Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2022

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, 2022

CHEMISTRY – HIGHER LEVEL

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 six questions in all.

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 marking Chemistry 2022

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*) (*i*) IDENTIFY: **calcium (Ca)** ions **/ Ca^{2+} //**
magnesium (Mg) ions **/ Mg^{2+}** (3 + 2)

(*ii*) EXPLAIN: sum of (all, total) **permanent and temporary** hardness **/**
due to sum of (all, total) dissolved **Ca^{2+} and Mg^{2+} (calcium and magnesium ions, salts** of **calcium and magnesium)** (3)

(*b*) (*i*) NAME: **Solocrome** Black **(Eriochrome** Black T, **Erio T**) (3)
[Black T insufficient]

(*ii*) WHAT: **wine (red, wine-red)** to **//**
to **blue** (2 × 3)
[Allow (3) for colours in reverse or for either correct colour where only one colour is stated.][Allow pink for wine (red, wine-red).]

(*c*) (*i*) WHAT: **10** (3)
[Accept answer in range 9 to 11]

(*ii*) WHY: to ensure **sharp (accurate, colour change at) end-point /**
to ensure only **calcium ions (Ca^{2+}, magnesium ions, Mg^{2+}, M^{2+}) detected /**
to ensure all **calcium ions (Ca^{2+}, magnesium ions, Mg^{2+}, M^{2+}) react (complex)** with edta **/**
to ensure **non-alkaline earth metal ions do not react (do not complex, not detected) /**
to ensure **indicator works properly /**
MY^{2-} stable only **at high pH** for calcium and magnesium **/**
alkaline conditions needed (acidic conditions unsuitable) for edta to complex with M^{2+} (calcium ions, Ca^{2+}, magnesium ions, Mg^{2+}) (3)

(*d*) DESCRIBE: **clamp vertically //**

fill above zero (mark) / fill to zero (mark) using dropper //

fill part **below tap (nozzle)** before adjusting to initial mark **//**

fill with clean dry **funnel //**

remove funnel before adjusting to initial mark **//**

ensure no bubbles (tap to remove bubbles) before adjusting to initial mark **//**

bottom of meniscus on zero (mark) //

read at eye-level / use card (paper, etc) behind burette when reading /
avoid parallax errors **when reading**

ANY THREE: (6 + 3 + 3)

(*e*) CALCULATE:

(*i*) 0**.000092** (**9.2 × 10^{-5}, 23/250000**) moles edta (3)

$\frac{9.2 \times 0.010}{1000}$ = 0**.000092** (**9.2 × 10^{-5}, 23/250000**) moles edta (3)

(*ii*) 0**.000092** (**9.2 × 10^{-5}, 23/250000**) moles of M^{2+} (3)

M^{2+} : edta = 1 : 1 ⇒ 0**.000092 (9.2 × 10^{-5}, 23/250000)** moles of M^{2+} (3)

(*iii*) 0**.00368** (**3.68 × 10^{-3}, 23/6250**) – 0**.0037** moles of M^{2+} removed from one litre (3)

0.000092 (9.2 × 10^{-5}, 23/250000) × 40
= 0**.00368** (**3.68 × 10^{-3}, 23/6250**) – 0**.0037** moles of M^{2+} removed from one litre
[Multiply (*ii*) by **40** essential.] (3)

or

$\frac{25.0 \times M}{1} = \frac{9.2 \times 0.010}{1}$ ⇒ M = 0**.00368 (3.68 × 10^{-3}, 23/6250)** – 0**.0037** moles of M^{2+} removed from one litre (3)

(*iv*) 0**.368** (**3.68 × 10^{-1}, 46/125**) – 0**.37** g $CaCO_3$ hardness removed from one litre (3)

= 0.00368 (3.68 × 10^{-3}, 23/6250) × 100*=
0**.368** (**3.68 × 10^{-1}, 46/125**) – 0**.37** g $CaCO_3$ hardness removed from one litre
[Multiply (*iii*) by **100*** essential.] (3)

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

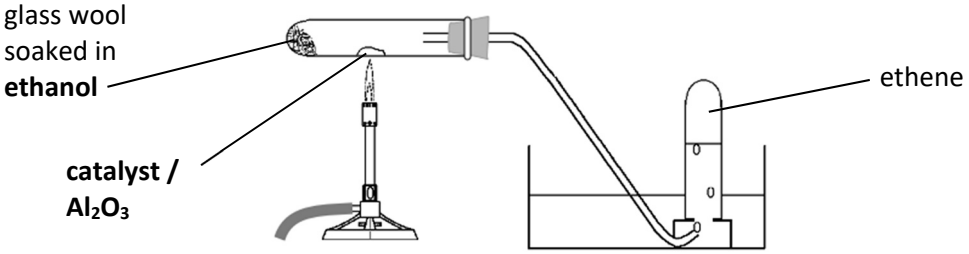
368 – 370 p.p.m. $CaCO_3$ hardness removed from one litre (3)

= 0.368 (3.68 × 10^{-1}, 46/125) × 1000 =
368 – 370 p.p.m. $CaCO_3$ hardness removed from one litre
[Multiply by **1000** essential.] (3)

[*1 mark to be deducted for **each** mathematical slip, e.g. transposing numbers, addition error in *M_r where atomic masses **shown** but added incorrectly, etc.*]

QUESTION 2

(*a*) DRAW: horizontal (slanting) **test tube** with glass wool soaked in **ethanol (C_2H_5OH)** and **delivery tube** shown **//**
heat source (flame, Bunsen burner) shown or indicated **under catalyst (alumina, Al_2O_3) near centre of test-tube //**
collection ethene **over water** shown (3 × 3)



[Ethanol, catalyst (Al_2O_3) must be labelled]
[Apply (–3) for description in words with no diagram.]

STATE: (*i*) **loosen stopper /**
remove delivery **tube** from water to avoid partial vacuum **/**
do not cool (do not remove (reduce) heat supply**, do not turn off Bunsen) with** delivery **tube in water** (4)

STATE: (*ii*) **avoid leaks** of flammable vapours from apparatus **/ ensure stoppers (tubing) tightly fitted / use grease (vaseline) to seal** apparatus **/ keep ethene (gas, vapour, ethanol) and flame (Bunsen) separate / close container of ethanol after set-up / remove flame (turn off gas)** at end **to avoid igniting ethene (product), etc** (4)
[Allow **keep flame away from hair (clothing, flammable materials)** or **tie back hair (remove loose clothing)** or **clear away flammable materials**]

(*b*) WHAT: (*i*) **purple (lilac, violet, pink) decolourises (to colourless)** (3)
[Correct order essential] [Decolourises alone insufficient]
[Clear not acceptable instead of colourless]

WHAT: (*ii*) **brown (red, orange, yellow) decolourises (to colourless)** (3)
[Correct order essential] [Decolourises alone insufficient]
[Clear not acceptable instead of colourless]

(*iii*) NAME: **addition** (3)

(*iv*) IDENTIFY: **1,2-dibromoethane ($BrCH_2CH_2Br$) / 2-bromoethanol ($BrCH_2CH_2OH$)** (3)
[Expanded structures acceptable and H's need not be shown explicitly.]

(*c*) (*i*) IDENTIFY: X: **charcoal / carbon / C //**
Y: **benzoic acid / C_6H_5COOH //**
Z: **potassium chloride (KCl) / water (H_2O)** (3 × 3)
[Take order of question unless responses are clearly labelled.]

WHAT: (*ii*) **evaporate (boil off)** some water **/ heat** filtrate **/**
put **flask** in **ice**-water **/ cool**ing of flask (solution) **/**
allow time (allow to stand, leave aside) for crystals to form (3)

WHAT: (*iii*) **wash with** ice-**cold water /**
dry crystals **(**crystals **dried) /**
recover more crystals from mother liquid (filter contents of collecting **flask again) /**
rinse (wash) flask in which crystals formed **into funnel** to collect more crystals (3)

(*iv*) HOW: m.p. **higher (increased, closer to 122 °C) /** m.p. **sharper (smaller range, narrower range)**
or

m.p. **impure (original)** crystals **lower /** m.p. **impure (original) broader range** (6)

[Ignore b.p. info in addition to m.p. info but b.p. info only is incorrect as a response].

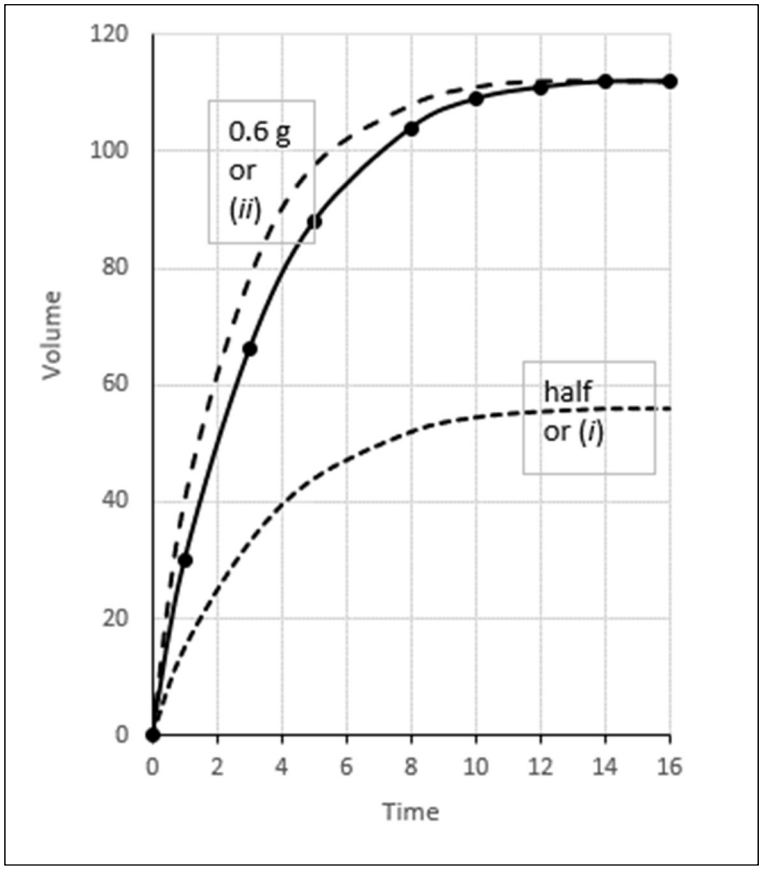
QUESTION 3

(*a*) WRITE: **$2H_2O_2 \rightarrow 2H_2O + O_2$ / $H_2O_2 \rightarrow H_2O + \frac{1}{2}O_2$** FORMULAE: (3) BALANCING: (2)

(*b*) GIVE: **corrosive / burns (blisters, bleaches)** skin **/ harmful (irritant) / causes fire (oxidizes** other substances**) / container could swell (pressure build-up in container) / releases oxygen (unstable, decomposes)** (3)
[Do not accept flammable.]

STATE: **reduce** amount **(dilute) / store (purchase) small quantities /** consider **substitute /** consider **eliminate / store cool (dry, secure, well ventilated, away from** non-compatible **substances, away from** non-compatible **chemicals, with other oxidising agents, in the dark, in ventilated containers, in plastic containers, with** small **hole in stopper) / do not store in glass bottles /** wear **PPE (gloves, eye protection) / avoid contact with skin (eyes, clothing) / use** appropriate **labels / use glycerine (glycerol, negative catalyst) / use as soon as possible** (3)
[Allow store in air-tight container.]

(*c*) PLOT: **axis labelled volume (*V*, O_2, cm^3) and axis labelled time (*t*, minutes) // appropriate correct numeric scales on both axes //**
careful **plotting of points other than (0, 0) //**
smooth curve of correct shape **through origin** (4 × 3)
[Pairs of points connected with straight lines do not give a smooth curve.]
[Deduct (3) for <u>each</u> of the following:
not on graph paper
more than one point plotted inaccurately.]
[Time *versus* volume graph acceptable.]



USE: (*i*) **13 – 14** minutes (3)

USE: (*ii*) **19 – 20** $cm^3 O_2$ per minute (3)

$\frac{total\ volume}{total\ time}$ =

78 ÷ 4 = **19.5** $cm^3 O_2$ per minute (3)

USE: (*iii*) **good tangent drawn to plotted curve at 4 minutes** (3)
any two points from tangent read correctly, e.g. (0, 40) and (8.2, 120) **/**
rise and run correctly read from tangent, e.g. 80 cm^3, 8.2 minutes

slope = **9.8** $cm^3 O_2$ per minute **[8.8 – 12.2]** $cm^3 O_2$ per minute (3)

$\frac{\mathbf{120-40}}{\mathbf{8.2-0}} = \frac{\mathbf{80}}{\mathbf{8.2}}$ **= 9.8** $cm^3 O_2$ per minute **[8.8 – 12.2]** $cm^3 O_2$ per minute (3)

[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.]

(*d*) SKETCH & LABEL ON GRAPH: (*i*) labelled **half** or **(*i*): rising curve, starting at origin, less steep than original // finishing at about 56 cm^3 (more than or equal to 50 cm^3 and not exceeding 60 cm^3)** (2 × 3)

[SKETCH marks are available if (*d*) (*i*) sketch is not on the graph in part (*c*) but labels essential.]

JUSTIFY: (*i*) **rate proportional to concentration / rate depends on concentration / yield (volume O_2) depends on number of moles** H_2O_2 concentration **/ yield (volume O_2) depends** on initial **concentration** of H_2O_2 (3)
[JUSTIFY marks can be awarded independently of SKETCH.]

SKETCH & LABEL ON GRAPH: (*ii*) labelled **0.6** g or **(*ii*): rising curve, starting at origin, initially as steep or steeper than plotted curve and finishing at 112 cm^3** (3)

[SKETCH marks are available if (*d*) (*ii*) sketch is not on the graph in part (*c*) but labels are essential.]
[Accept original graph if clearly labelled **0.6** g or **(*ii*)** or candidate explains clearly that both curves are identical.]

JUSTIFY: (*ii*) steeper because catalyst has **greater surface area (more active sites) /**
as steep because **small quantity of catalyst sufficient /**
same yield because **catalyst** quantity **has no effect on yield (catalyst** amount can **affect rate) /**
same yield because **same concentration of hydrogen peroxide (H_2O_2)** used both times (3)

[JUSTIFY marks can be awarded independently of SKETCH.]

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*) REFER: Li, Na, and K (groups) have similar chemical **properties //**
atomic mass (weight) of Na (one) is **average of (midway between)** those of **Li and K (of other two) / mass number of one (Na) is average** of the mass numbers **of** the **others (Li and K) / 23 = (7 + 39) ÷ 2** (2 × 3)

(*b*) WHY: electron in **outer** energy **level (shell, *n* = 3) has more energy /**
electron in **excited (higher, outer)** state **has more energy /**
electron in **inner** energy **level (shell, *n* = 2) has less energy /**
electron **loses energy /** electron moves **from higher to lower energy** level **/**
$E_2 - E_1 = hf$ (6)

(*c*) WHY: second **electron** comes **from full (new, closed) shell (**main **energy level, 1*s* sublevel, 1*s* orbital) /**
second **electron** comes **from shell (**main **energy level) closer to nucleus /**
second outermost **electron** comes **from 1st** main **energy level (shell)**
while first electron comes **from 2nd /**
1st electron removed (lost) is only electron in outer (2nd) shell (main **energy level) /**
second **electron** comes **from** a species with **a stable helium (noble gas)**
electron **configuration /**
second **electron less (not) shielded (screened)** from nucleus than first (6)

Where 6 marks not awarded above 5 marks may be awarded any *one* of the following.
more difficult to remove electron from positive ion than from neutral atom **/**
greater electrostatic force (attraction) between Li^+ **ion and electron /**
1st electron farther from nucleus / 2nd **electron closer to nucleus /**
ionic radius smaller than atomic radius **/**
effective nuclear charge increased when 1st electron is removed /
more protons than electrons in the ion

(*d*) WHAT: (*i*) **red / crimson //**
(*ii*) **blue-green / green** (4 + 2)
[Allow blue/green for blue-green]

(*e*) STATE: **at the same temperature and pressure //**
equal volumes of gases have **equal (the same) number(s) of particles (atoms, molecules, moles)** (2 × 3)
[Do not allow s.t.p for 'same temperature and pressure'.]

(*f*) CALCULATE: 0.**2**00 g (6)

18.3 × 12 = **219.6** g C (3)

1098 carats = 219.6 g

⇒ one carat = $\frac{219.6}{1098}$ = 0.**2**00 g (3)

or

$\frac{18.3}{1098}$ = $\frac{\mathbf{1}}{\mathbf{60}}$ **(0.016667)** moles C per carat (3)

⇒ one carat = 0.016667 × 12

= 0.**2**00 g (3)

or

$\frac{1098}{18.3}$ = **60** carats per mole C (per 12 g C) (3)

⇒ one carat = $\frac{\mathbf{12}}{\mathbf{60}}$

= 0.**2**00 g (3)

(*g*) WHAT: **iron(II) sulfate ($FeSO_4$),** ammonium **iron(II) sulfate) / $(C_6H_5)_2NH$ (diphenylamine)** and **NH_4Cl (ammonium chloride) / copper (Cu) //**
concentrated **sulfuric acid (H_2SO_4)**
or
sodium hydroxide (NaOH) solution **//**
aluminium (Al) / copper (Cu) / zinc (Zn) (4 + 2)

(*h*) IDENTIFY: (*i*) **aluminium sulfate (alum, $Al_2(SO_4)_3$) / polyacrylamide ($-CH_2CHCONH_2-)_n$ / sodium silicate (Na_2SiO_3, Na_4SiO_4, $Na_6Si_2O_7$, etc) / sodium aluminate ($NaAlO_2$, $NaAl(OH)_4\cdot(H_2O)_x$, $Na_2O\cdot Al_2O_3$, $Na_2Al_2O_4$) / aluminium chlorohydrate ($Al_nCl_{3n-m}(OH)_m$) / iron(II) sulfate ($FeSO_4$) / iron(III) chloride ($FeCl_3$) / calcium oxide (CaO) / calcium hydroxide ($Ca(OH)_2$)**
[Allow polyelectrolyte]

(*ii*) **sodium fluoride (NaF) / hexafluorosilicic acid (H_2SiF_6) / sodium fluorosilicate (Na_2SiF_6) /**
[Allow **fluoride** ion **(F^-), fluoride** salt.]
(4 + 2)

(*i*) WHAT: **iodine (I_2) //**
hydrogen (H_2) (4 + 2)
[Allow I and H]

(*j*) WHICH: **ethyne (C_2H_2)** (6)

(*k*) CALCULATE: **72**.0 mg (6)

M_r aspirin ($C_9H_8O_4$) = 180

0.146 × 180* = **26.28**0 g aspirin (3)

26.28 ÷ 365 = 0.**072**0 **(9/125)** g per day (2)

⇒ 0.0720 × 1000 = **72**.0 mg per day (1)

or

M_r aspirin ($C_9H_8O_4$) = 180

0.146 ÷ 365 = **4 × 10^{-4} (1/2500)** mol per day (2)

4 × 10^{-4} × 180* = 0.**072**0 **(9/125)** g per day (3)

⇒ 0.0720 × 1000 = **72**.0 mg aspirin per day (1)

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

(*l*) **A** WRITE: $CO_2 + H_2O \rightarrow H_2CO_3$

$H_2CO_3 \rightleftharpoons (\rightarrow) HCO_3^- + H^+$ / $H_2CO_3 + H_2O \rightleftharpoons (\rightarrow) HCO_3^- + H_3O^+$ //

$HCO_3^- \rightleftharpoons (\rightarrow) CO_3^{2-} + H^+$ / $HCO_3^- + H_2O \rightleftharpoons (\rightarrow) CO_3^{2-} + H_3O^+$ (2 × 3)

or

$H_2CO_3 \rightleftharpoons (\rightarrow) HCO_3^- + H^+ \rightleftharpoons (\rightarrow) CO_3^{2-} + 2H^+$ (6)

[Allow **$2H_2CO_3 \rightleftharpoons (\rightarrow) HCO_3^- + CO_3^{2-} + 3H^+$** or

$2H_2CO_3 + 3H_2O \rightleftharpoons (\rightarrow) HCO_3^- + CO_3^{2-} + 3H_3O^+$]

or

B WHAT: **molecules occupy (at) lattice points //**

held together by (contain) **intermolecular (van der Waals, London, dispersion, dipole-dipole, hydrogen) bonds (forces, interactions)** (2 × 3)

QUESTION 5

(*a*) (*i*) WHICH: very tiny number of alpha particles **rebound**ed / **last (third)** observation

(*ii*) WHAT: atom has a small **nucleus /** mass of atom concentrated at **small (dense) core / nuclear model** of atom **/** atom is **mostly empty space**

(5 + 3)

(*b*) DEFINE: (*i*) 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)

DEFINE: (*ii*) **average mass of atom** of the element **/**
average of mass of isotopes of the element **taking abundances into account (as they occur naturally) /**
average of mass numbers of isotopes of the element **taking abundances into account (as they occur naturally) //**
compared to (relative to, based on) 1/12th **carbon–12** isotope (2 × 3)

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

HOW MANY: (*i*) **4** (3)

HOW MANY: (*ii*) **10** (3)

USE: **loses (donates) 4*s* (4th shell, outer 2) electrons / becomes $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$** (3)
[Allow **loses 2 electrons** or **forms Ca^{2+}**]

EXPLAIN: to **satisfy octet rule /**
Ca^{2+} has stable **noble gas (Ar, argon)** electron **configuration /** Ca^{2+} **isoelectronic with Ar /**
Ca^{2+} has stable full **outer octet ($ns^2\ np^6$)** electrons **/**
8 electrons in outer shell (energy level) is stable **/**
6 electrons in outer *p*-sublevel (*p*-subshell) is stable **/**
full outer *p*-sublevel (*p*-subshell) is stable **/**
closed shell of valence electrons (8 valence electrons, valence sublevels full) is stable **/**
Group 2 (II) element / forms ionic bonds (3)
['Set of full sublevels stable' unacceptable and does not cancel.]
['To have full outer shell which is stable' incorrect but does not cancel.]
[USE must be correct for EXPLAIN to be awarded marks.]
[Answers for USE and EXPLAIN may be combined.]

(*d*) (*i*) DEFINE: spontaneous **decay (disintegration, break-up, splitting) of** an unstable atomic **nucleus** (**of** atomic **nuclei**) **//**
with emission of different (one or more) types of radiation /
with emission of alpha (α) particles, **beta (β)** particles and (or) **gamma (γ)** rays (2 × 3)

(*ii*) COPY & COMPLETE: $^{222}_{86}\mathrm{Rn} \rightarrow \mathbf{^{218}_{84}Po} + {}^{4}_{2}\mathrm{He}$ **/** $^{86}_{222}\mathrm{Rn} \rightarrow \mathbf{^{84}_{218}Po} + {}^{2}_{4}\mathrm{He}$ (3)

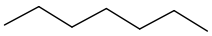
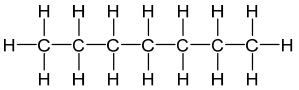
(*iii*) SUGGEST: lead into gold **involves nuclear reaction (change to nucleus, change of atomic number, change of Z, change in number of protons) /**
chemical reactions involve electrons only /
transmutation (changing atoms of **one element into** atoms of **another) not a chemical reaction** (3)

QUESTION 6

(*a*) COMPARE: (*i*) petrol has **smaller (lower)** average M_r **/ diesel (gas oil)** has **greater (higher)** average M_r
[Allow 'petrol lighter' or 'diesel heavier'.]

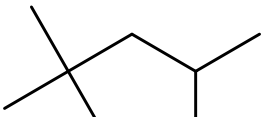
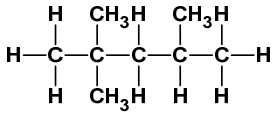
COMPARE: (*ii*) petrol has **lower** boiling point **/ diesel (gas oil)** has **higher** boiling point (3 + 2)

(*b*) (*i*) EXPLAIN: **measure of (tendency, ability)** of a fuel **to resist knocking (autoigniting, pre-igniting, igniting too early, pinking, igniting before spark) / measure of (tendency, ability)** of a fuel **to knock (autoignite, pre-ignite, ignite too early, pink, ignite before spark) / fuel performance rating based on its equivalence to a certain mixture of hydrocarbons (alkanes)** (3)

GIVE: (*ii*) **heptane //**
DRAW: (*ii*) **$CH_3(CH_2)_5CH_3$ /**  **/**  (2 × 3)

[Hs need not be shown explicitly in expanded structure.]
DRAW (*ii*) marks only available for structure of heptane.

GIVE: (*iii*) **2,2,4-trimethylpentane //**
[Allow (2) for 2,4,4-trimethylpentane or trimethylpentane.]
[Allow (2) for *iso*-octane.]
DRAW: (*iii*) **$CH_3C(CH_3)_2CH_2CH(CH_3)CH_3$ / $CH_3C(CH_3)_2CH_2CH(CH_3)_2$ /**

 **/**  (2 × 3)

[Hs need not be shown explicitly in expanded structure.]
DRAW (*iii*) marks only available for structure of 2,2,4-trimethylpentane.]

(*iv*) WHAT: **branched** chain **/ branching** on chain **/ short chain** (3)

(*c*) (*i*) SUGGEST: too **reactive (reacts, explosive, flammable, combustible) / density** too **low /** too **light /** Earth's **gravity** too **weak (escapes from atmosphere)** (3)
[Allow unstable.]

(*ii*) GIVE: **electrolysis** of water **/ coal gasification / shift reaction / dehydrocyclisation (reforming)** hydrocarbons (3)

(*iii*) 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 an equation** describing a reaction **react** completely (2 × 3)

(*iv*) EXPLAIN: **same reaction (1 mole hydrogen combines with oxygen in each** case**) / Hess' law / only initial and final states (only reactants and product**s**) affect heat of (energy change for) reaction** not the pathway (3)

(*v*) USE: **–74.9** kJ mol^{-1} (12)

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

206.2 (3) = (**–110.5**) kJ (3) – $\Delta H_{formation\ methane}$ **–(– 241.8)** kJ (3) **/**
206.2 (3) = (**–110.5**) kJ (3) – $\Delta H_{formation\ methane}$ **+ 241.8** kJ (3) **/**
206.2 (3) = **131.3** kJ (6) – $\Delta H_{formation\ methane}$ **/**

$\Delta H_{formation\ methane}$ = **–206.2** (3) **–110.5** (3) **+ 241.8** (3) **/**
–206.2 (3) **+ 131.3** kJ (6) **//**

$\Delta H_{formation\ methane}$ = **–74.9** (3) kJ mol^{-1}

or

$CO + 3H_2 \rightarrow CH_4 + H_2O$		ΔH =	**–206.2** kJ	(3)
$C + ½O_2 \rightarrow CO$		ΔH =	**–110.5** kJ	(3)
$H_2O \rightarrow H_2 + ½O_2$		ΔH =	**241.8** kJ	(3)
$C + 2H_2 \rightarrow CH_4$	$\Delta H_{formation\ methane}$ =		**–74.9** 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 not acceptable.

Where final answer for ΔH = +**74.9** kJ mol^{-1} apply the marking scheme but the maximum mark is 9.

QUESTION 7

(*a*) EXPLAIN: (*i*) state reached when **rates of forward and reverse reactions** are **equal / $r_f = r_r$**

EXPLAIN: (*ii*) state reached at which these **concentrations (they)** are **constant /**
$\frac{[\mathbf{C}]^c[\mathbf{D}]^d}{[\mathbf{A}]^a[\mathbf{B}]^b}$ **= constant (*K*, K_c)** for *a*A + *b*B ⇌ *c*C + *d*D **/** $\frac{[\mathbf{CH_3OH}]}{[\mathbf{CO}][\mathbf{H_2}]^2}$ **= constant (*K*, K_c)***
[Square brackets essential.] (6 + 2)

(*b*) (*i*) WRITE: $K_c = \frac{[\mathbf{CH_3OH}]}{[\mathbf{CO}][\mathbf{H_2}]^2}$ * (6)
[Square brackets essential.]
[*Marks for (*b*) (*i*) may be awarded for this expression given in (*b*) (*ii*) CALCULATE.]

(*ii*) CALCULATE: K_c = 0**.148 (4/27) –** 0**.15** (4 × 3)

Let *x* = number of moles of CO that reacts. 25% of 5.0 mol reacts ⇒ *x* = 1.25 mol

	$CO_{(g)}$	+	$2H_{2\,(g)}$	⇌	$CH_3OH_{(g)}$	
Initially:	5.0 mol		10.0 mol		0 mol	
Change:	**– *x*** mol		**– 2*x*** mol		**+ *x*** mol **/**	
Equil:	**5.**0 **– *x*** mol		**10.**0 **– 2*x*** mol		***x*** mol	(3)

But *x* = 1.25 mol

Equil:	**3.75** mol		**7.5** mol		**1.25** mol	(3)

Divide by 5.0

Equil:	$\frac{3.75}{5}$ =		$\frac{7.5}{5}$ =		$\frac{1.25}{5}$ =	
	0**.75** mol/l		**1.5** mol/l		0**.25** mol/l	(3)

$K_c = \frac{0.25}{0.75(1.5)^2}$ = 0**.148 (4/27) –** 0**.15** (3)

or

Let *x* = number of moles of CO that reacts. 25% of 5.0 mol reacts ⇒ *x* = 1.25 mol

	$CO_{(g)}$	+	$2H_{2\,(g)}$	⇌	$CH_3OH_{(g)}$	
Initially:	5.0 mol		10.0 mol		0 mol	
Change:	**– *x*** mol		**– 2*x*** mol		**+ *x*** mol **/**	
Equil:	**5.**0 **– *x*** mol		**10.**0 **– 2*x*** mol		***x*** mol	(3)

Divide by 5.0

Equil:	$\frac{\mathbf{5.0}-\boldsymbol{x}}{\mathbf{5}}$ mol/l		$\frac{\mathbf{10.0}-\mathbf{2}\boldsymbol{x}}{\mathbf{5}}$ mol/l		$\frac{\boldsymbol{x}}{\mathbf{5}}$ mol/l	(3)

But *x* = 1.25 mol

Equil:	0**.75** mol/l		**1.5** mol/l		0**.25** mol/l	(3)

$K_c = \frac{0.25}{0.75(1.5)^2}$ = 0**.148 (4/27) –** 0**.15** (3)

or

Let x = number of moles per litre of CO that reacts. 25% of 1.0 mol/l reacts ⇒ x = 0.25 mol/l

	$CO_{(g)}$	+	$2H_{2\,(g)}$	⇌	$CH_3OH_{(g)}$	
Initially:	5.0 mol		10.0 mol		0 mol	
Divide by 5.0						
Initially:	**1**.0 mol/l		**2**.0 mol/l		0 mol/l	(3)
Change:	**–** ***x*** mol/l		**– 2*x*** mol/l		**+** ***x*** mol/l **/**	
Equil:	**1.0 –** ***x*** mol/l		**2.0 – 2*x*** mol		***x*** mol /l	(3)
But x = 0.25 mol/l						
Equil:	0**.75** mol/l		**1.5** mol/l		0**.25** mol/l	(3)

$K_c = \frac{0.25}{0.75(1.5)^2}$ = 0**.148 (4/27) – 0.15** (3)

[Do not allow mixing and matching of marks between boxes.]
[Allow use of incorrect K_c expression from (*b*) (*i*) WRITE in (*b*) (*ii*) CALCULATE without further penalty.]

(*c*) WHAT: **rate(s) increased (changed, decreased) / reaction(s) faster (speeded up, changed, slower) / equilibrium reached faster (sooner, later) / activation energy (E_a) decreased (altered, increased) /** provides **faster (lower energy, higher energy, alternative) pathway (mechanism)** for reaction **/ lower (higher) energy intermediate** formed **/ more cost effective (cheaper) / more efficient / takes less (more) time** to reach equilibrium (6)
[Allow '**lower** operating **temperature** feasible']

(*d*) (*i*) 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.]

(*ii*) HOW: **higher** yield methanol **/ more** methanol **/** (3)

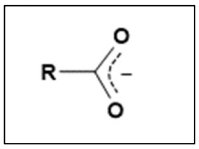
(*ii*) EXPLAIN: because **adding carbon monoxide (CO, a reactant) is a stress** on equilibrium **/** because some added **carbon monoxide (CO) reacts (a reactant get used up) /** because **forward reaction (rhs, product side) favoured / equilibrium shifts to right (product side) /** to **relieve stress (reduce pressure) /** because **Le Châtelier's principle** applies (3)
[(*ii*) HOW must be correct for (*ii*) EXPLAIN to be awarded marks.]

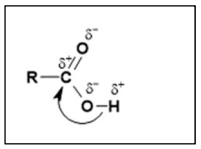
(*iii*) HOW: **unchanged / no effect** (3)

(*iii*) EXPLAIN: because **temperature constant (stays at 250 °C) /** because **only temperature** change **affects (changes)** K_c **/** because K_c **only temperature dependent /** because K_c **unaffected (unchanged) by changes in concentration /** because **concentrations (amounts) of other** equilibrium **substances (chemicals) also change keeping** K_c **constant** (3)
[(*iii*) HOW must be correct for (*iii*) EXPLAIN to be awarded marks.]

QUESTION 8

(*a*) (*i*) EXPLAIN: –COOH (RCOOH) **loses (donates) proton (H^+) forming $–COO^–$ ($RCOO^–$) /**
–COOH (RCOOH) **dissociates forming $–COO^–$ ($RCOO^–$) and proton (H^+, H_3O^+) //**

($–COO^–$) stable (exists as **resonance** hybrid**) /**
delocalised charge on $–COO^–$ ($RCOO^–$) /  **/**

inductive effect draws electrons away from H of **OH** bond **/**  **/**

δ^+ carbonyl carbon draws electrons away from H of **OH** bond (2 × 3)
[R in boxes need not be shown explicitly.]
[Allow carboxylate ion for **$–COO^–$** or **$RCOO^–$**]

(*ii*) GIVE: **reaction with sodium (or other alkali metal) /**
Na (K) + C_2H_5OH → (6)
[No marks deducted for incorrect product.]

(*iii*) WHAT: **nothing / no reaction / no** (3)

EXPLAIN: ethanol **not strong**ly **acid**ic **/** ethanol **weak**ly **acid**ic **/**
Na_2CO_3 not strongly **basic enough / no resonance stabilisation in ethoxide ion / no inductive effect in ethanol** (3)
[EXPLAIN marks available only if WHAT marks awarded.]

(*b*) (*i*) WRITE: **$HCOOH + C_2H_5OH \rightarrow HCOOC_2H_5 + H_2O$ /**
$HCO_2H + C_2H_5OH \rightarrow HCO_2C_2H_5 + H_2O$ FORMULAE: (3) BALANCING: (3)
[Accept CH_2O_2 for methanoic acid, C_2H_6O for ethanol and $C_3H_6O_2$ for ethyl methanoate]

(*ii*) GIVE: **ethyl methanoate** ✔

(*iii*) HOW MANY: **one / 1** ✔

(*iv*) CLASSIFY: **substitution** ✔

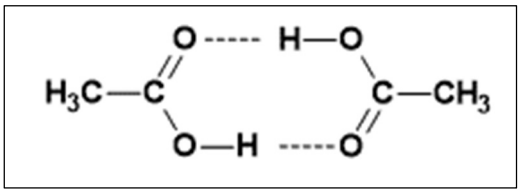
(*v*) IDENTIFY: **methyl ethanoate (CH_3COOCH_3)** ✔

(*vi*) IDENTIFY: **methanol / CH_3OH //**
sodium methanoate / HCOONa ✔ ✔

(*vii*) EXPLAIN: **hydrogen (H) bonds** in ethanoic acid **/**
no hydrogen (H) bonds in methyl methanoate /

dipole-dipole (van der Waals, London, dispersion) forces (bonds, interactions) in methyl methanoate /

ethanoic acid (the carboxylic acid) **dimerises /**
effective **molecular formula** ethanoic acid **$C_4H_8O_4$ /**
ethanoic acid **forms (becomes) $(CH_3COOH)_2$ /**
effective **molecular mass (M_r)** ethanoic acid **increased (**is **120) /**



✔

(*ii*) to (*vii*) has SEVEN POINTS: [(2 × 6) + (4 × 3) + 2]

QUESTION 9

(*a*) DEFINE: pH = **– log$_{10}$[H$^+$] /** pH = **– log$_{10}$[H$_3$O$^+$] /**
minus log base 10 **hydrogen ion concentration** expressed **in moles per litre**
[Deduct 1 for brackets not square.]

WRITE: K_w = **[H$_3$O$^+$][OH$^-$] /** K_w = **[H$^+$][OH$^-$]**
[Deduct 1 for brackets not square.]

[6 + 2]

(*b*) STATE: **only** for **aqueous solutions /**
only for **dilute solutions /**
not effective (reliable, accurate, suitable) in **concentrated solutions /**
temperature dependent (pH scale 0 - 14 only at **25 °C)** (6)

(*c*) CALCULATE:

(*i*) [H$_3$O$^+$] = **2.2 × 10^{-6} – 2.24 × 10^{-6}** moles per litre (6)

[H$_3$O$^+$] = **inverse log (– 5.65) /** [H$_3$O$^+$] **= antilog(– 5.65) /** [H$_3$O$^+$] = **10$^{-5.65}$** (3)

$\Rightarrow$ [H$_3$O$^+$] = **2.2 × 10^{-6} – 2.24 × 10^{-6}** moles per litre (3)

(*ii*) [OH$^-$] = **4 × 10^{-9} – 5 × 10^{-9}** moles per litre (6)

K_w = [H$_3$O$^+$][OH$^-$] / K_w = 2.2 × 10^{-6} [OH$^-$]
$\Rightarrow$ [OH$^-$] **= 1.0 × 10^{-14} ÷ 2.2 × 10^{-6}** (3)
= 4 × 10^{-9} – 5 × 10^{-9} moles per litre (3)
or
pOH = 14 – 5.65 = **8.35** (3)

[OH$^-$] = inverse log (– 8.35) / [OH$^-$] = antilog(– 8.35) / [OH$^-$] = 10$^{-8.35}$

$\Rightarrow$ [OH$^-$] = **4 × 10^{-9} – 5 × 10^{-9}** moles per litre (3)

(*d*) (*i*) WHAT: **20**.0 cm^3 (3)

(*ii*) DEDUCE: A: **1**.0 M
B: 0**.5** M
C: **1**.0 M
D: **1**.0 M (4 × 3)
[Take order of the question unless responses are clearly labelled.]

(*iii*) WHICH: **C** (3)

JUSTIFY: **lower initial pH (D has higher initial pH, greater initial H$^+$ concentration, [H$^+$] higher initially) /** from graph **1.8 – 1.9 < 2.2 – 2.3 /**
***K*a of C > *K*a of D shown by calculation using pH = –log$\sqrt{Ka[acid]}$ /**
first part of **C** curve **below D** curve **/**
C curve **becomes steep (vertical) first /**
C has longer vertical part to its pH curve **/**
C curve **closer to** strong **A** curve (3)
[JUSTIFY marks only available if WHICH marks awarded.]

(*iv*) WHAT: **CH$_3$COO$^-$** (3)

QUESTION 10

(*a*) (*i*) WHAT: **obeys *PV* = *nRT* (the gas laws, Boyle's law, Charles' law)** at all temperatures and pressures **/ obeys kinetic theory** assumptions perfectly (4)

or

point particles (particles of no volume) colliding elastically /
point particles (particles of no volume) colliding with no net **loss nor gain of energy /**
point particles (particles of no volume) with no forces between them /
point particles (particles of no volume) with collisions of negligible duration (4)
[Allow molecules instead of particles above.]

(*ii*) STATE: **high temperature //**
low pressure (2 × 3)

(*iii*) WHICH: **helium (He)** (3)

JUSTIFY: **atoms (particles*) most (more) like point masses / atoms (particles*) have smallest (smaller) volume) / smallest (smaller) atoms (particles*) /**
weakest (weaker) intermolecular (van der Waals, London, dispersion) forces (bonding, interactions) / fewest (fewer) electrons (only 2 electrons) / lowest (lower) boiling point (3)
[Allow helium atoms (particles*) have smallest (smaller) mass or are lightest (lighter).]
[*Accept molecules for particles here]
[WHICH marks must be awarded before JUSTIFY marks available.]

(*iv*) CALCULATE: **2** (9)

$pV = nRT$ / $n = \frac{pV}{RT} \Rightarrow$

99000 × 0.06 (99 × 60) = *n* × 8.3 × 295 / *n* $= \frac{\mathbf{99000 \times 0.06}}{\mathbf{8.3 \times 295}} (\frac{\mathbf{99 \times 60}}{\mathbf{8.3 \times 295}})$ (3)

n = **2.4**3 moles (3)

$n = \frac{m}{M_r}$ / $M_r = \frac{m}{n}$

$\Rightarrow M_r = \frac{4.85}{2.43}$ = 2.00 = **2** (3)

[If final answer is not a whole number (–1).]

or

$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2} \Rightarrow$

$\frac{\boldsymbol{V_1 \times 101325}}{\mathbf{273.15}} = \frac{\mathbf{0.06 \times 99000}}{\mathbf{295}} (\frac{\mathbf{60 \times 99}}{\mathbf{295}})$ (3)

$V_1 = 0.0543$ m^3

volume gas at s.t.p = 22.4 × *n* = 54.3 litres $\Rightarrow$ *n* = **2.4**24 moles (3)

$n = \frac{m}{M_r}$ / $M_r = \frac{m}{n}$

$\Rightarrow M_r = \frac{4.85}{2.424}$ = 2.00 = **2** (3)

[If final answer is not a whole number (–1).]

[If no marks are awarded for the calculation allow (3) for $pV = nRT$ or $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$]

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

ACCOUNT: **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)

PREDICT: (*i*) **tetrahedral / tetrahedron** (3)
[Diagram of tetrahedron acceptable] [Do not apply cancellation where 2-d diagram of 4 bond pairs around silicon drawn.]

PREDICT: (*ii*) **v**-shaped **/ bent / angular** (3)
[Diagram acceptable] [Do not apply cancellation where 2-d diagram of 2 bond pairs and 2 lone pairs around sulfur drawn.]

PREDICT: (*iii*) trigonal **pyramid**al (3)
[Diagram of pyramidal arrangement of bonds acceptable]
[Do not apply cancellation where 2-d diagram of 3 bond pairs and 1 lone pairs around phosphorus drawn.]

WHICH: (*iv*) **silicon tetrachloride ($SiCl_4$)** (2)

WHICH: (*v*) **sulfur dichloride (SCl_2)** (2)
[Allow **S–Cl** bond]

(*c*) CALCULATE: (*i*) 0**.036** moles H or 0**.018** moles H_2 (3)

0.018 × 2 = 0**.036** mol H or 0**.018** moles H_2 (3)

CALCULATE: (*ii*) 0**.032** moles C (8)

$\frac{3.584}{56^*}$ = 0**.064** moles KOH (4)

⇒ 0.064 ÷ 2 = 0.032 moles CO_2

⇒ 0**.032** moles C (4)

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

CALCULATE: (*iii*) 0**.002 / 2 × 10^{-3} / 1/500** moles S (4)

$\frac{44.8}{22400}$ = 0.002 / 2 × 10^{-3} / 1/500 moles SO_2

⇒ 0**.002 / 2 × 10^{-3} / 1/500** moles S (4)

CALCULATE: (*iv*) 0**.004 / 4 × 10^{-3} / 1/250** moles N or 0**.002 / 2 × 10^{-3} / 1/500** moles N_2 (4)

$\frac{2.4 \times 10^{21}}{6 \times 10^{23}}$ = 0.004 / 4 × 10^{-3} / 1/250 moles NO_2

⇒ 0**.004 / 4 × 10^{-3} / 1/250** moles N or 0**.002 / 2 × 10^{-3} / 1/500** moles N_2 (4)

WHAT: **$C_{16}H_{18}N_2O_4S$** (6)

C : H : N : O : S = 0**.032 :** 0**.036 :** 0**.004 :** 0**.008 :** 0**.002** (2)

[Number of **moles H atoms** and number of **moles of N atoms** essential.]

Divide C : H : N : O : S **ratio by smallest number of moles** (3)

⇒ **$C_{16}H_{18}N_2O_4S$** (1)

[Last mark available **ONLY** for **$C_{16}H_{18}N_2O_4S$**]

[Full marks available where elements are not in alphabetical order.]

QUESTION 11

(*a*) DEFINE: (*i*) **gain** of electrons

(*ii*) **decrease** in oxidation number (4 + 3)

(*iii*) EXPLAIN: hydrogen (H) **more electronegative / metal**s **less electronegative / metal**s **more electropositive / more electronegative atom assigned (acquires, gets) negative charge** (3)

(*iv*) WHAT: **2** (3)

(*v*) ASSIGN & BALANCE: $\mathbf{2Mn^{2+} + 5BiO_3^- + 14H^+ \rightarrow 2MnO_4^- + 5Bi^{3+} + 7H_2O}$

+2 (II) +5 (V) +7 (VII) +3 (III) (9)

Award marks for correct oxidation numbers of manganese and bismuth only.
[Allow Roman numerals for oxidation states.]

$Mn^{2+} + BiO_3^- + H^+ \rightarrow MnO_4^- + Bi^{3+} + H_2O$
+2 **+7** (3)

$Mn^{2+} + BiO_3^- + H^+ \rightarrow MnO_4^- + Bi^{3+} + H_2O$
+5 **+3** (3)

$\mathbf{2Mn^{2+} + 5BiO_3^- + 14H^+ \rightarrow 2MnO_4^- + 5Bi^{3+} + 7H_2O}$ (3)

[Plus signs need not be given for the positive oxidation numbers, i.e. +2 and 2 equally acceptable]

(*vi*) IDENTIFY: reducing agent: **Mn^{2+} / Mn(II)** (3)

[Correct charges essential throughout where substances are in bold in (v) and (vi).]

(*b*) WHAT: (*i*) purple (violet, pink) to **colourless** (6)
[Decolourises sufficient.][Clear unacceptable.]

WHAT: (*ii*) blue solution to brick **red precipitate (solid)** (3)

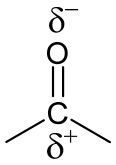
(*iii*) IDENTIFY: **ethanoic acid (CH_3COOH) / ethanoate** ion **(CH_3COO^-) / sodium ethanoate (CH_3COONa)** (3)

(*iv*) IS: ethanal very **easily** oxidised **/** ethanal **easy** to oxidise (3)

(*v*) WRITE: **$Cu^{2+} + e^- \rightarrow Cu^+$** (3)

(*vi*) DESCRIBE: **carbon (C) is partially (slightly) positive**ly charged **/ carbon (C) is δ^+ // oxygen (O) is partially (slightly) negative**ly charged **/ oxygen (O) is δ^-**
(2 × 2)

or



(4)

(*vii*) EXPLAIN: **hydrogen bonding (attraction) between δ^- oxygen**s **of ethanal and δ^+ hydrogen**s **of water /**
attraction (intermolecular forces, intermolecular bonding, dipole-dipole interactions) between δ^+ carbon of ethanal and δ^- oxygen of water (partial charges of ethanal and water) (3)
[Information acceptable in diagrammatic form, labels not essential]

(*c*) (*i*) EXPLAIN: minimum combined **energy of colliding particles (molecules) //**
for reaction to take place between them
or
minimum combined **energy** of particles (molecules) **//**
for (of) effective collisions

TWO PARTS : (2 × 2)

[*At least one mention of collisions or colliding is essential for full marks*.]

(*ii*) WHAT: **100** kJ mol^{-1} (3)

(*iii*) BY HOW: **40** kJ mol^{-1} (3)

(*iv*) WHAT: **–30** kJ mol^{-1} (3)

(*v*) EXPLAIN: **catalyst in a different phase from reactants** and products **/**
boundary between catalyst and reactants (3)
[State for phase unacceptable.]

(*vi*) DESCRIBE: reactants (hydrogen and oxygen, gases) **adsorbed on (chemisorbed, bond** weakly **with, attracted onto, attached to) surface (catalyst, platinum) /**
reactants (hydrogen and oxygen, gases) **occupy (adsorbed onto) active sites** on catalyst **//**

reaction takes place **on surface (catalyst) /**
bonds in reactant molecules **weak**en **(stretch, break)** on surface (catalyst) **/**
product (water) bonds begin to **form** on surface (catalyst) **/**
higher **concentration (more hydrogen and oxygen)** on surface (catalyst) **/**
reactants (hydrogen and oxygen) closer **together** on surface (catalyst) **/**
activation energy (E_a) lowered on surface (catalyst) **/**
reactants (hydrogen and oxygen) orientated (oriented) correctly for reaction on surface (catalyst) **/**
intermediate formed on surface (catalyst) **//**

product (water) leaves (desorbs from) surface (catalyst) ANY TWO: (6 + 3)

(*d*)

A (*i*) EXPLAIN: **break-up (splitting up, decomposing) //**
using light (uv, electromagnetic radiation) (2 × 4)

(*ii*) WRITE: $\mathbf{O_3 \rightarrow O_2 + O^{\bullet}}$ (3)
[Dots to label free radicals not essential.]

(*iii*) STATE: **refrigerant /** liquid for **air conditioner units, fridges, freezers /**
propellant / gas for **aerosols /**
to make **expanded polystyrene (expanded plastic, plastic foam, insulation foam, packaging foam) / fire extinguishant, etc** (6)

(*iv*) SHOW: $\mathbf{CCl_3F \rightarrow CCl_2F^{\bullet} + Cl^{\bullet}}$ **//**
$\mathbf{O_3 + Cl^{\bullet} \rightarrow O_2 + ClO^{\bullet}}$ **//**
$\mathbf{ClO^{\bullet} + O^{\bullet} \rightarrow O_2 + Cl^{\bullet}}$ (3 × 2)
[Dots to label free radicals not essential.]

(*v*) EXPLAIN: $\mathbf{CH_4 + Cl^{\bullet} \rightarrow CH_3^{\bullet} + HCl}$ (2)
[Dots to label free radicals not essential.]

or

B (*i*) EXPLAIN: zinc **high**er **up electrochemical series** than iron **/** zinc **more easily oxidised** than iron **/** zinc **corrodes first (before iron) /** zinc **more electropositive** than iron **/ iron more electronegative** than zinc (3)

(*ii*) IDENTIFY: **zinc (Zn) / magnesium (Mg) / aluminium (Al)** (3)

(*iii*) HOW: metal of sacrificial anode **high**er **up electrochemical series** than iron **/**
metal of sacrificial anode **more easily oxidised** than iron **/**
metal of sacrificial anode **corrodes first (before iron) /**
metal of sacrificial anode **more electropositive** than iron **/**
iron more electronegative than metal of sacrificial anode **/**
metal of sacrificial anode **dissolves as** a **salt /**
steel (hull) becomes cathode of electrochemical cell (3)

(*iv*) WHAT: has **aluminium oxide (Al_2O_3)** thickened **coat (on surface, on outside)** (6)

(*v*) WRITE: **$Pb^{2+} + 2e^- \rightarrow Pb$** FORMULAE: (2) BALANCING: (2)

$Br^- \rightarrow$ Br + $e^- \rightarrow$ **$\frac{1}{2}Br_2 + e^-$ / $2Br^- \rightarrow$** 2Br + $2e^- \rightarrow$ **$Br_2 + 2e^-$**
FORMULAE: (2) BALANCING: (2)

(*vi*) HOW: **movement of ions (Pb^{2+} and Br^-)** (2)