Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2016

Marking Scheme

Chemistry

Higher Level

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

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

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

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

Future Marking Schemes

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

Introduction

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

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

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

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

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

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

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

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

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 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		Bunmharc	Marc Bónais
301 - 303	29		351 - 353	14
304 - 306	28		354 - 356	13
307 - 310	27		357 - 360	12
311 - 313	26		361 - 363	11
314 - 316	25		364 - 366	10
317 - 320	24		367 - 370	9
321 - 323	23		371 - 373	8
324 - 326	22		374 - 376	7
327 - 330	21		377 - 380	6
331 - 333	20		381 - 383	5
334 - 336	19		384 - 386	4
337 - 340	18		387 - 390	3
341 - 343	17		391 - 393	2
344 - 346	16		394 - 396	1
347 - 350	15		397 - 400	0

Candidates are required to answer eight questions in all.

These must include at least two questions from Section A.

All questions carry equal marks (50).

QUESTION 1

(*a*)   MEASURE: use 25 cm³ **pipette (burette)** //
previously **rinsed with deionised (distilled, pure) water** //
and previously **rinsed with vinegar (solution it will contain, sample)** //
pipette: **read at eye-level / read bottom of meniscus / bottom of meniscus on the mark /
allow drainage time / last drop to remain (not to be shaken out, blown out) /
drain under gravity / touch (tip, tap)** pipette **against** wall of **flask**
burette: **read at eye-level / jet (part below tap) full / vertical / read bottom of meniscus**

<div align="right">ANY THREE: (3 × 3)</div>

   DILUTE: transfer to 250 cm³ **volumetric flask** //
previously **rinsed with deionised (distilled, pure) water** //
fill with deionised water until **bottom of meniscus is on mark** //
stopper and **invert** flask **a number of times** / stopper and **mix contents thoroughly**

<div align="right">ANY TWO: (2 × 3)</div>

[Award marks for reference to '*bottom of meniscus*' once only in (*a*).]

(*b*)   NAME: **phenolphthalein**   (3)

   WHAT: from **pink (purple)**   (3)
   to **colourless**   (3)
   [Colours reversed unacceptable.] ['*Clear*' unacceptable for '*colourless*'.]

(*c*)   CALCULATE: (*i*)   **0.0015 (1.5 × 10⁻³) moles**   (6)

$$M = \frac{1.20 \times 2}{40^*} = \textbf{0.06**} \text{ M} \quad (3)$$

$$\frac{25 \times 0.06}{1000} = \textbf{0.0015} \text{ moles/25 cm}^3 \quad (3)$$

/

$$\frac{1.20}{20} = \textbf{0.06} \text{ g in 25 cm}^3 \quad (3)$$

$$\frac{0.06}{40^*} = \textbf{0.0015} \text{ moles/25 cm}^3 \quad (3)$$

/

$$\frac{1.20}{40^*} = \textbf{0.03} \text{ moles/500 cm}^3 \quad (3)$$

$$\frac{0.03}{20} = \textbf{0.0015} \text{ moles/25 cm}^3 \quad (3)$$

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

   (*ii*)   **0.00008 (8 × 10⁻⁵) moles per cm³**   (6)

0.0015 moles CH₃COOH   (3)

0.0015 ÷ 18.75 =
0.00008 (8 × 10⁻⁵) moles per cm³   (3)

/

$$\frac{18.75 \times M}{1} = \frac{25 \times 0.06}{1} \quad / \quad \frac{18.75 \times M}{1} = \frac{25 \times Molarity**}{1}$$

$$M = \textbf{0.08***} \text{ M} \quad (3)$$

$$\frac{0.08}{1000} = \textbf{0.00008 (8 × 10}^{-5}\text{) moles per cm}^3 \quad (3)$$

(*d*)   FIND: (*i*)   **0.8 M**   (3)

0.00008 × 1000 × 10 = **0.8** moles/L   (3)   /   0.08 (Molarity***) × 10 = **0.8** moles/L   (3)

   (*ii*)   **4.8 % (w/v)**   (6)

0.8 × 60* = **48** g/L   (3)
$$\frac{48}{10} = 4.8 \text{ g/100 cm}^3 = \textbf{4.8 \% (w/v)} \quad (3)$$

/

0.8 ÷ 10 = **0.08** moles/100 cm³   (3)
0.08 × 60* = 4.8 g/100 cm³ = **4.8 % (w/v)**   (3)

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

(*e*)   WHAT: anhydrous sodium carbonate titrated **with a strong acid {hydrochloric acid (HCl),
sulfuric acid (H₂SO₄), nitric acid (HNO₃)}** //
acid titrated **with sodium hydroxide (NaOH)** solution   (3 + **2**)
[Award (3) for correct titrations in reverse order.]

QUESTION 2

(*a*)   DESCRIBE: **bromine (Br$_2$) solution (water) / acidified potassium manganate(VII) {permanganate} / (KMnO$_4$/H$^+$) / (MnO$_4^-$/H$^+$)**   (3)

                    **decolourises (changes to colourless, colour disappears) //
if unsaturated**

                    or

                    no change in colour //
                    if saturated   (2 × 3)
                    ['*Clear*' unacceptable for '*colourless*'.]

(*b*) (*i*)   DEDUCE: *D:* **ethanal / CH$_3$CHO**   (3)

        DESCRIBE: add **Fehling's (Benedict's)** solution (reagent) /
                    add **ammoniacal silver nitrate** (**Tollens'** reagent**) //**

                    heat gently /
                    blue (Cu^{2+}) solution reacts (changes, is reduced) /
                    colourless (Ag(I), silver(I) oxide, Ag$_2$O, Ag$^+$) reacts (changes, is reduced) //

                    giving brick **red** precipitate / giving **silver** mirror (metal)
                    [DESCRIBE marks only available if DEDUCE marks awarded.]
                    [Reagent and observations must match.]   (3 × 3)
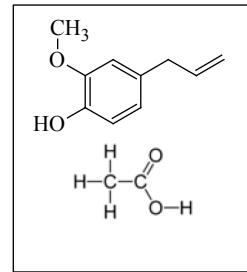
  (*ii*)   IDENTIFY: *C:* **eugenol //**
                   E: **ethanoic** acid **(CH$_3$COOH) /**   (2 × 3)

        WHAT: **two layers / organic (cyclohexane) layer and aqueous layer**   (3)
                    [*Marks available from a diagram*.]

  (*iii*)   WRITE: **2CH$_3$COOH + Mg → (CH$_3$COO)$_2$Mg + H$_2$**
                                            FORMULAE: (3) BALANCING: (3)

(*c*) (*i*)   DESCRIBE: **sample (crystals) in** melting point (m.p.) capillary **tube in melting** point **block (apparatus, in Thiele tube) shown in diagram / sample (crystals) on aluminium (melting) block shown in diagram //
heat** slowly while observing crystals / **heat source shown or labelled in diagram //
record (note) temperature** range at which **melting occurs / record (note) the melting** point **temperature**

                                                  (3 × 3)
                  ['Record melting point' insufficient even where thermometer shown or mentioned.]
                  [Maximum (6) if no diagram or no labels.]

  (*ii*)   WHICH: **G / F is less pure**   (3)

  (*iii*)   NAME: **recrystallisation**   **(2)**

QUESTION 3

(*a*) DRAW: **both reactants in flask (reaction vessel), e.g. A, B or C below, and one reactant labelled with name or formula** [hydrogen peroxide added from dropping funnel not acceptable] //

flask **connected to graduated container, e.g. X or Y below**, for oxygen collection / [graduations marked or collecting graduated container labelled] (**4 + 4**)

H₂O₂
MnO₂

graduated cylinder **X**

gas syringe **Y**
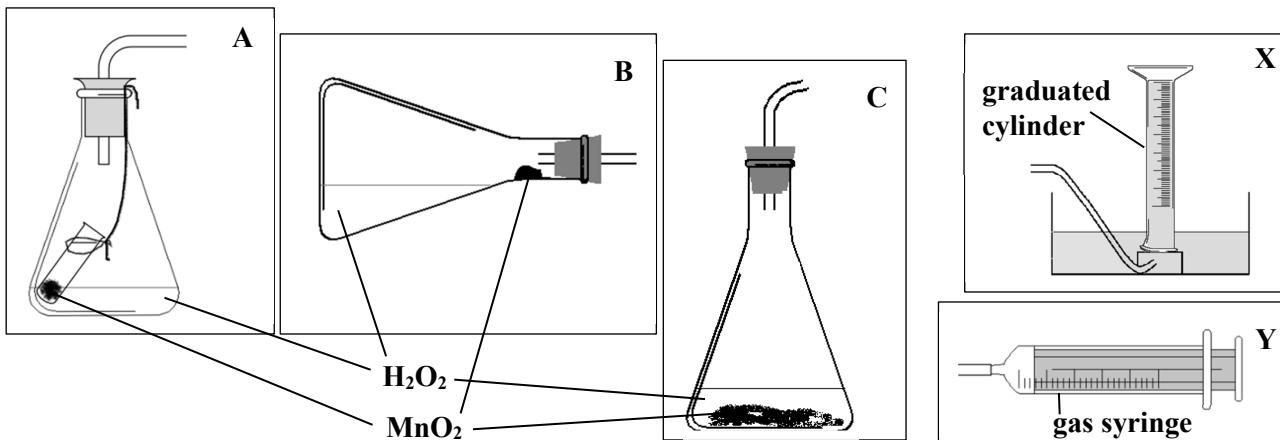
(*b*) PLOT: **both axes correctly labelled (*V / volume / cm³ / oxygen / O₂ / time / t / minutes / min*)**(3)

appropriate, correct numeric scales on both axes (3)

careful plotting to give smooth curve of correct shape through origin for run A // careful plotting to give smooth curve of correct shape through origin for run B

(6 + 3)

same volume of oxygen produced by run A and run B (3)
[*Time versus volume* acceptable.]
[(6) marks deducted if graph not on graph paper or not on same set of axes.]
[Deduct (3) for any one of the following: kink in curve due to inaccurate plotting of one or more points; points connected with straight lines; curve not through origin.
Apply once to each curve.]

	Time (minutes)	0.0	1.0	2.0	3.0	5.0	6.5	8.0	9.5	11.0	12.0
Run A	Volume (cm³)	0	25	41	54	72	78	81	82	82	82
Run B	Volume (cm³)	0	16	28	39	57	68	76	80	82	82

(1.0, 39)

(6.0, 82)

Time (minutes)	Run A Volume (cm³)	Run B Volume (cm³)
0.0	0	0
1.0	25	16
2.0	41	28
3.0	54	39
5.0	72	57
6.5	78	68
8.0	81	76
9.5	82	80
11.0	82	82
12.0	82	82

Time (minutes)
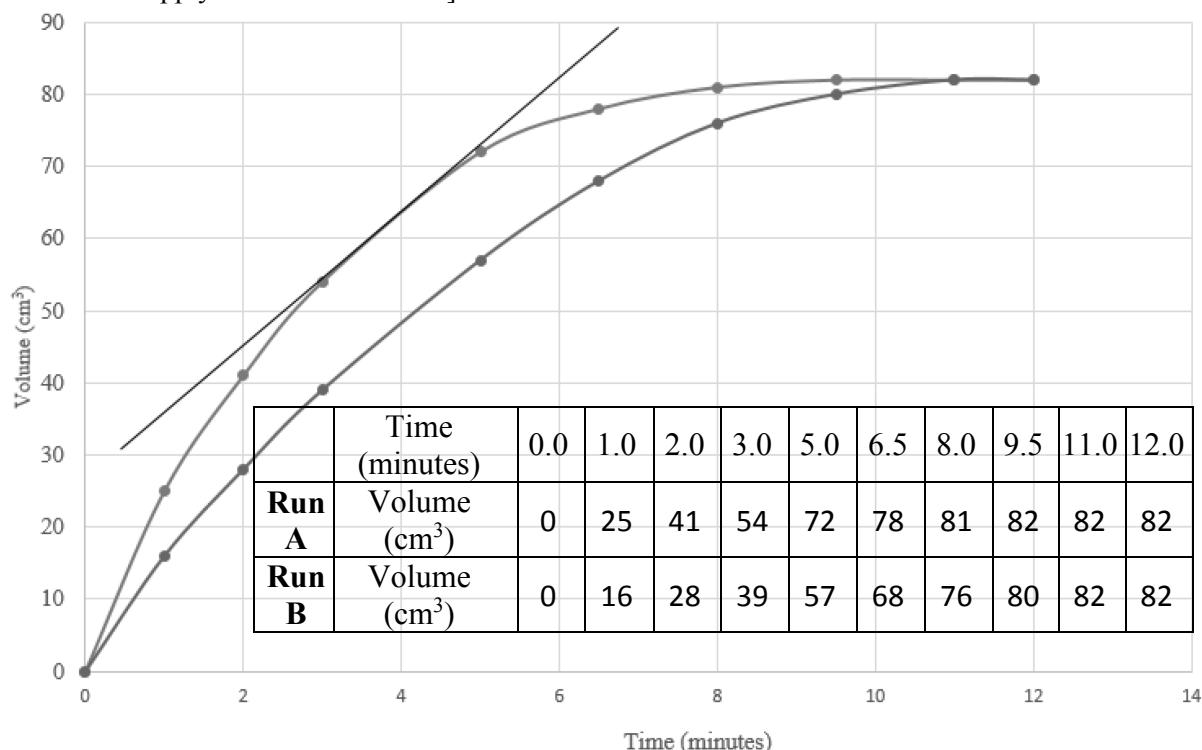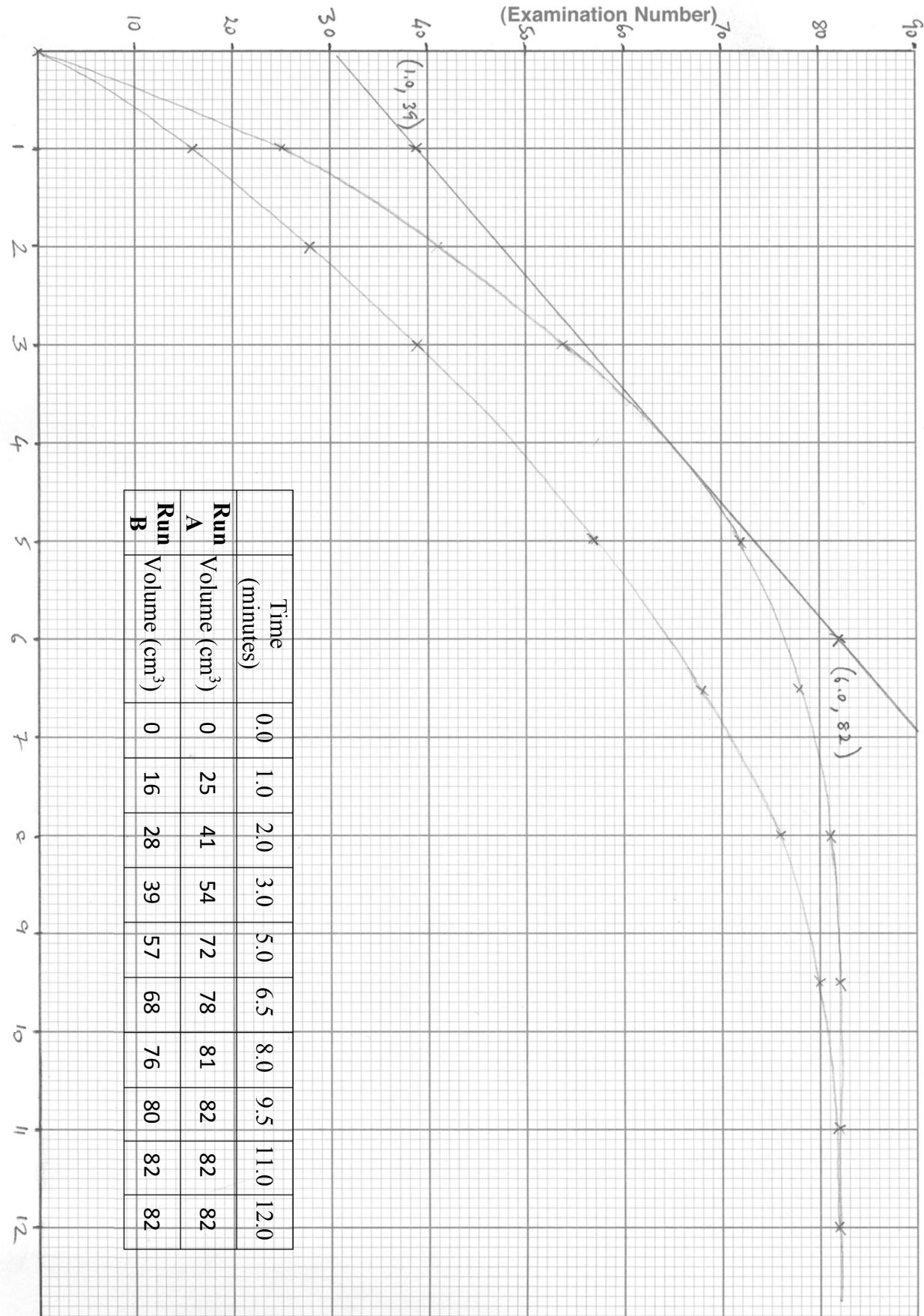
(*c*)   CALCULATE: **8.2 – 9.5** cm^3 oxygen per minute   (6)

> **any two points from a tangent drawn at 4 minutes on curve A**
>   e.g. (6.0, 82) and (1.0, 39)
>
> $\frac{82-39}{6.0-1.0} = \frac{43}{5.0}$ = **8.6 [8.2 – 9.5]** cm^3 oxygen per minute   (6)

[Deduct 1 mark if tangent correctly drawn at 4 minutes on curve B.]

(*d*)   WHICH: (*i*)   **A //**
                 (*ii*)   **B**   (2 × 3)

        WHAT: **surface adsorption** / **heterogeneous** [Accept 'surface *ab*sorption']   (3)

        SUGGEST: **greater surface area (more finely divided, smaller particle size) / more active / purer /
                  B has less surface area (less finely divided, greater particle size) / B less pure / B less
                  active / B poisoned**   (3)
                  [SUGGEST marks available only if (6) awarded for WHICH.]

(*e*)   WHAT: (*i*)   **oxidiser / oxidising** reagent **/ oxidises / causes other substances to burn readily**
                                                                                       (3)
                  ['*Health problems*' and '*dangerous*', are unacceptable but do not cancel.]
                  ['*Burns*', '*corrosive*' and '*flammable*' are unacceptable and cancellation applies.]

                 (*ii*)   **harmful / irritating / irritant**   (3)
                  ['*Health problems*', '*dangerous*', '*toxic*', '*poisonous*' are acceptable.]
                  [Allow '*corrosive*'.]

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*)   WHAT: (*i*)   **27** //

                  (*ii*)   **59**   (2 × 3)

(*b*)   DESCRIBE: **electrons** (**negative particles, negative charges, –'s) in** //

                  positive (+) sphere (ball, mass, material, matter)   (2 × 3)

                  [Marks may be obtained from a clear diagram with correct charges indicated.]

(*c*)   EXPLAIN: **nitrogen is** relatively **stable** //

                  has a **half-filled 2*p* (outer) sublevel (subshell)** /

                  has **three half-filled 2*p* (outer) orbitals**

                  [2*p* allowed for an electron configuration but other points in bold, e.g. 'half-filled',
                  must be stated.]

                  or

                  oxygen is relatively **unstable (less stable)** //

                  doesn't have half-filled 2*p* (outer) sublevel (subshell) / **doesn't have
                  three half-filled 2*p* (outer) orbitals / has only one full outer 2*p* orbital /
                  loss** of electron **gives half-filled 2*p* (outer) sublevel (subshell)** /
                  loss of electron **gives three half-filled 2*p* (outer) orbitals**   (2 × 3)

                  [2*p* allowed for an electron configuration but other points in bold, e.g. 'half-filled',
                  must be stated].

(*d*)   DISTG: sigma (σ) bond is formed by **head (end) on overlap of** atomic **orbitals** //

                  pi (π) bond is formed by **sideways overlap of** atomic **orbitals**

                  [Orbitals need not be mentioned twice.] [Allow 'collision' of orbitals.]

                  or

                  sigma (σ) bond **symmetrical with respect to rotation about bond axis** //

                  pi (π) bond **asymmetrical (unsymmetrical) with respect to rotation about bond axis**

                  or

                  sigma (σ) bond **allows rotation about the bond axis** //

                  pi (π) bond **does not allow rotation about the bond axis**

                  or

                  sigma (σ) bond **has one region of overlap** //

                  pi (π) bond **has two regions of overlap**

                  or

                  in a multiple (double, triple) covalent bond //

                  sigma (σ) bond is strongest bond / sigma (σ) bond **is formed first / pi (π) bond is weaker
                  bond / pi (π) bond is formed only after a sigma (σ)** bond has already been formed

                                                                                          (2 × 3)

                  [Marks may be obtained from good clear diagrams with orbitals labelled if present.]

(*e*)   WRITE: (*i*) H_3PO_4 //

                  (*ii*) HPO_4^{2-} (2 × 3)

(*f*)   WHAT: there is a **simple (small) whole number ratio of volumes** of reactants and products //
at the same (constant) conditions of **temperature and pressure**   (2 × 3)
['*Amounts*' not acceptable for '*volumes*'.]
['*At all conditions of temperature and pressure*' and '*at s.t.p.*' are not acceptable.]

(*g*)   HOW MANY: **0.0125 / 0.013** moles   (6)

Mr = **132***   (3)

$= \dfrac{1.65}{132} =$ **0.0125 / 0.013** moles   (3)

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

(*h*)   HOW: **add barium chloride {barium nitrate, BaCl₂, Ba(NO₃)₂} solution / add barium ions (Ba²⁺) solution //**
white precipitate dissolves (disappears, clears) in (on addition of) dilute **hydrochloric acid (HCl)**   (2 × 3)

(*i*)   WHAT: **minimum** combined **energy of colliding particles (molecules, atoms, ions) //**
for reaction to take place between them

or

minimum combined **energy** of particles (molecules, atoms, ions) //
for effective collisions   (2 × 3)
[*Mention of collisions essential but only once*.]

(*j*)   GIVE: **molecules (compounds, substances, bonds, groups of atoms, functional groups) absorb** infrared radiation //
of different (characteristic, certain) frequencies (wavelengths, energies)   (2 × 3)

(*k*)   **A** DESCRIBE: **scrubbing (reaction) //**
with limestone (calcium carbonate, CaCO₃, CaO, hydroxide compounds, amines, zeolites, etc)
(2 × 3)
[Equations acceptable, e.g. $CaO + SO_2 \rightarrow CaSO_3$ (6) *or* $CaCO_3 + SO_2 \rightarrow CaSO_3 + CO_2$ (6)]

   B NAME: **x-ray //**
crystallography   (2 × 3)

QUESTION 5

(*a*) (*i*) DISTING: *ground state:* **n = 1 / lowest (first, nearest nucleus) energy** level / **1***s* / **minimum amount of energy / stable** state //

        excited states: **n > 1 / n = 2, 3,** etc / **n = 2,** etc / **2***s*, 2*p*, **3s,** etc / **n = 2 and higher / energies (energy levels) other than n = 1 / higher energies / higher energy (unstable) levels**   (2 × 3)
[For excited states accept 'any (a, some) higher energy level' but not '*the* higher energy level'.]

[Allow a diagram with three concentric circles around a nucleus, with the innermost circle labelled ground state for (6).]

(*ii*) HOW: add **heat {energy, electricity, light, electromagnetic radiation}**   (3)

(*iii*) EXPLAIN: [Information must be given verbally.]
excited **electron falls** back **from n = 3, 4,** etc / excited **electron falls** back **from n = 3,** etc / excited **electron falls** back **from n > 2 (***E*$_{n>2}$**)** / excited **electron falls from higher energy levels** //

to second shell (energy level) / to n = 2 / to *E*$_2$ //

the energy lost is **emitted as light {electromagnetic radiation (energy)} of different frequencies (colours, wavelengths)** / the energy lost is **emitted as different (discrete)** *hf* **(***hv***, photon(s)) / different electron transitions correspond to different lines (colours, frequencies)**   (3 × 3)

[Allow two *correct* examples of Balmer series electron energy changes, e.g. $E_3 − E_2$ and $E_6 − E_2$, for the first two points.]

    WHAT: **Balmer** series   (3)

(*iv*) EXPLAIN: **no corresponding electron transition (energy loss) / no corresponding excited state / electron cannot exist (be) between** energy **levels / electron cannot exist (be) between n = 3 and n = 4 / electron transition cannot originate from (terminate) between** energy **levels / electron transition cannot originate from between n = 3 and n = 4 / electron transition cannot terminate between n = 3 and n = 2 /** $E_n − E_2 \neq hf$ (*hv*) for yellow / **no whole (natural, integer) number solution for n in** $E_n − E_2 = hf$ (*hv*) for yellow   (3)

(b) DESCRIBE: (3 × 3)

Method 1	Method 2	Method 3	
clean a **platinum (nichrome) wire*** (rod, probe) in concentrated hydrochloric acid (HCl)	**soak wood (splint, stick)** overnight in water / **use damp (wet) wood (splint, stick)**	**prepare** a solution of the given **salt in water and ethanol (propanol)**	(3)
dip rod in salt and hold salt in hot (blue) part of Bunsen **flame**	**dip splint (stick) in salt and hold** salt in hot (blue) part of Bunsen **flame**	**spray** solution **onto (into)** hot (blue) part of Bunsen **flame**	(3)
red (crimson) colour is a positive result for lithium	**red (crimson)** colour is a positive result for lithium	**red (crimson)** colour is a positive result for lithium	(3)

*[Allow 'inoculating loop', or 'spatula' for 'platinum wire'.]
[Clear labelled diagram for some or all points acceptable.]

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

or

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

DISTGINGUISH: **2p sublevel consists (is made up) of** three 2p **orbitals** of equal energy /
2p sublevel accommodates (has, holds) no more than **6 electrons** but each of the 2p **orbital**s **accommodates {has, hold**s} no more than **2 of these electrons**   (3)

WRITE: **1s^2 2s^2 2p^6 3s^2 3p^6 4s^2**   **(4)**
[*Allow subscripts instead of superscripts.*]
[*Arrows to represent numbers of electrons acceptable but sublevel symbols must be given.*]

EXPLAIN: **4s** sublevel **lower in energy than the 3d / electrons fill the 4s** sublevel **before the 3d**
                                                                                                  (4)

QUESTION 6

(*a*) NAME: **fractionation / fractional distillation** **(5)**

IDENTIFY: **boiling (condensing) point (temperature)** (6)

(*b*) GIVE: (*i*) **aviation (airplane, jet) fuel** / home **heating (cooking, lighting)** oil (3)

(*ii*) **roofing** / **road** making / **waterproofing** (3)

(*c*) NAME: **isomerisation** (3)

NAME: **dehydrocyclisation / reforming** (3)

EXPLAIN: **improves (increases) octane rating (number) / reduces tendency** of fuel **to cause knocking** / by **making molecules (compounds, hydrocarbons) that are branched (cyclic, shorter chained)** (3)

CALCULATE: **237.6** kJ (9)

$$C_8H_{18} \rightarrow 8C + 9H_2 \qquad\qquad \Delta H = \mathbf{250.1}\ \text{kJ} \quad (3)$$
$$8C + 5H_2 \rightarrow C_8H_{10} \qquad\qquad \Delta H = \mathbf{-12.5}\ \text{kJ} \quad (3)$$
$$C_8H_{18} \rightarrow C_8H_{10} + 4H_2 \qquad\qquad \Delta H = \mathbf{237.6}\ \text{kJ} \quad (3)$$
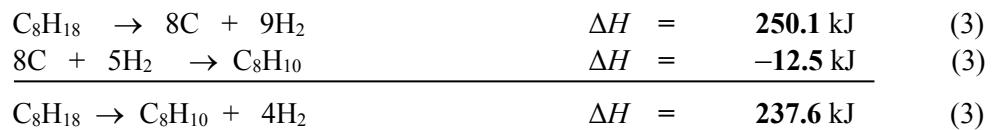
or

$$\Delta H_{\text{reaction}} = \Sigma \Delta H_{\text{f(products)}} - \Sigma \Delta H_{\text{f(reactants)}}$$
$$\Delta H_{\text{reaction}} = \mathbf{-12.5}\ (3) - \mathbf{[-250.1]}\ (3)$$
or $\quad \Delta H_{\text{reaction}} = \mathbf{-12.5}\ (3) + \mathbf{250.1}\ (3)$
$$= \mathbf{237.6}\ \text{kJ mol}^{-1} \qquad (3)$$

(*d*) DEDUCE: $\mathbf{C_7H_{14}}$ (6)
[Accept structure.]

(*e*) DRAW:

(*i*) octane	(*ii*) 2,2,4-trimethylpentane	(*iii*) ethylbenzene
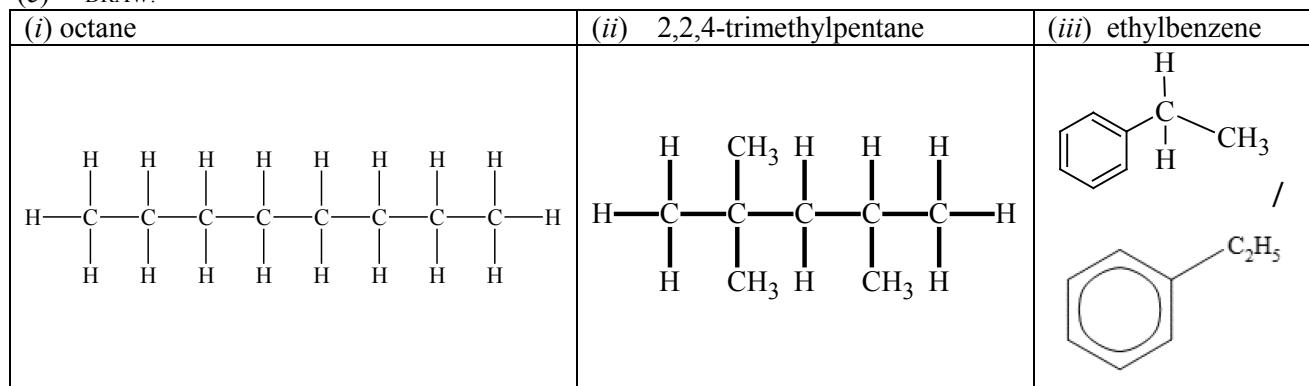
(3 × 3)

[Accept correct condensed structures, e.g. $CH_3(CH_2)_6CH_3$, $(CH_3)_3CCH_2CH(CH_3)_2$, $C_6H_5C_2H_5$.]
[Allow Hs to be omitted in fully expanded structures or fully expanded parts of structures.]

QUESTION 7

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

     PREDICT: (*i*)   **low** temperature **//**
[Allow 'decrease in temperature'.]

     EXPLAIN: **favours (results in, produces more) exothermic (heat producing)** reaction /
high temperature would **favour (result in, produce more) endothermic (heat absorbing)** reaction / favours **forward reaction** which **is exothermic / does not favour reverse reaction which is endothermic**   **(2 × 3)**

     PREDICT: (*ii*)   **high** pressure **//**
[Allow 'increase in pressure'.]

     EXPLAIN: **favours (results in, produces) fewer moles (molecules) / favours smaller volume / low pressure** would **favour (result in, produce) more moles (molecules) / favours greater volume /** favours **fewer moles (molecules) on right /** favours **smaller volume on right / does not favour more moles (molecules) on left / does not favour greater volume on left /**

                                                               (2 × 3)

               [EXPLAIN marks only available if PREDICT marks awarded.]

     EXPLAIN: reaction (rate) too **slow (uneconomical, costly)** at low temperatures   **(3)**

(*b*)   STATE: **no effect / none**   **(3)**

     EXPLAIN: in presence of catalyst **sulfur trioxide (SO_3) produced and used up at same rate /**
catalyst **alters (speeds up) rate of forward and reverse** reactions **equally**   **(3)**
[EXPLAIN marks linked to STATE marks.]['*Equilibrium reached faster*' insufficient on its own.]

(*c*)   WRITE: $K_c = \dfrac{[SO_3]^2}{[SO_2]^2[O_2]}$ (6)

CALCULATE: **196000 / 1.96 × 10^5**   (18)

Initially: moles $SO_2 = \dfrac{96}{64^*}$ = **3/2 (1.5)** and moles $O_2 = \dfrac{24}{32^*}$ = **3/4 (0.75)**   (3)

At equilibrium: moles $SO_3 = \dfrac{112}{80^*}$ = **7/5 (1.4)**   (3)

	2SO$_2$ +	O$_2$ ⇋	2SO$_3$
Equil mol:	**0.1** (3)	**0.05** (3)	1.4
Equil M:	**0.002**	**0.001**	**0.028**

Divide by 50. (3)

	2SO$_2$ +	O$_2$ ⇋	2SO$_3$
Initial M:	**0.03**	**0.015**	
Equil M:			**0.028**

Divide by 50. (3)

	2SO$_2$ +	O$_2$ ⇋	2SO$_3$
Equil M:	**0.002** (3)	**0.001** (3)	0.028

$K_c = \dfrac{(0.028)^2}{(0.002)^2(0.001)}$ = **196000 / 1.96 × 10^5**   (3)

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

[*Where* **K$_c$** *incorrect, e.g. inverted, allow consequential marks for calculation –*
up to a maximum of 15 marks.]

2SO$_2$ +	O$_2$ ⇋	2SO$_3$	
Start (moles): $\dfrac{96}{64^*}$ = **3/2(1.5)**	$\dfrac{24}{32^{**}}$ = **3/4 (0.75)**		(3)
Equil (moles):		$\dfrac{112}{80^{***}}$ = **7/5 (1.4)**	(3)
Equil (moles): $(1.5 - 2x)$	$(0.75 - x)$	$2x = 1.4$	$x = 0.7$
Equil (moles): **0.1**	**0.05**	1.4	(2 × 3)
Equil (mol/L): $0.1 \div 50 =$ **0.002**	$0.05 \div 50 =$ **0.001**	$1.4 \div 50 =$ **0.028**	Divide by 50. (3)

$K_c = \dfrac{(0.028)^2}{(0.002)^2(0.001)}$ = **196000 / 1.96 × 10^5**   (3)

2SO$_2$ +	O$_2$ ⇋	2SO$_3$	
Start (moles): $\dfrac{96}{64^*} = \dfrac{3}{2}$ / **1.5**	$\dfrac{24}{32^{**}} = \dfrac{3}{4}$ / **0.75**		(3)
Equil (moles):		$\dfrac{112}{80^{***}} = \dfrac{7}{5}$ / = **1.4**	(3)
Start (mol/L): $1.5 \div 50$ = **0.03**	$0.75 \div 50$ = **0.015**	0 / $1.4 \div 50 =$ 0.028	Divide by 50. (3)
Equil (mol/L): $(0.03 - 2x)$	$(0.015 - x)$	$2x = 0.028$	$x = 0.014$
Equil (mol/L): **0.002**	**0.001**	0.028	(2 × 3)

$K_c = \dfrac{(0.028)^2}{(0.002)^2(0.001)}$ = **196000 / 1.96 × 10^5**   (3)

QUESTION 8

(*a*)   NAME: **A = ethanol / ethyl alcohol //**
                    B = poly(ethene) / polyethene / polythene / polyethylene   (2 × 3)

(*b*)   IDENTIFY: **aluminium oxide / alumina / Al_2O_3 / concentrated sulfuric acid / H_2SO_4**   (3)
      WHAT: **elimination / dehydration**   (3)
   HOW: **tetrahedral to planar**   (3)

(*c*)   WHAT: **substitution**   (3)

      DESCRIBE: *initiation*:

> Where a candidate refers in name or in a drawing to methane instead of ethane and/or methyl instead of ethyl and/or ethane instead of butane, deduct 3 marks but only once in (*c*).

homolysis (splitting, fission) of chlorine molecule (Cl_2) into free radicals (atoms, $Cl^\bullet$, Cl) by ultraviolet (uv) light /

$$Cl_2 \xrightarrow{\text{uv}} 2Cl^\bullet \;/\; Cl_2 \xrightarrow{\text{uv}} 2Cl \qquad (3)$$

propagation (*1*):
chlorine radical (atom, $Cl^\bullet$, Cl) reacts with ethane molecule (C_2H_6) giving hydrogen chloride (HCl) and an ethyl radical ($C_2H_5^\bullet$) /
$$Cl^\bullet + C_2H_6 \rightarrow HCl + C_2H_5^\bullet \;/\; Cl + C_2H_6 \rightarrow HCl + C_2H_5^\bullet \qquad (3)$$
[Hydrochloric acid **not** acceptable for HCl and cancellation applies.]
[Where C_2H_5 used instead of $C_2H_5^\bullet$ deduct 3 marks but only once in (*c*).]
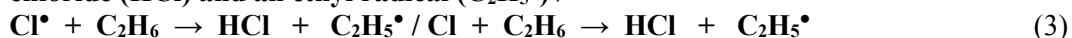
propagation (*2*):
ethyl radical ($C_2H_5^\bullet$) reacts with chlorine molecule (Cl_2) giving mono chloroethane (C_2H_5Cl) and a chlorine radical (atom, $Cl^\bullet$, Cl) /
$$C_2H_5^\bullet + Cl_2 \rightarrow C_2H_5Cl + Cl^\bullet \;/\; C_2H_5^\bullet + Cl_2 \rightarrow C_2H_5Cl + Cl \qquad (3)$$

> Where a radical is referred to as an ion or where a diagram shows a radical but the description refers to an ion cancellation applies *each* time.
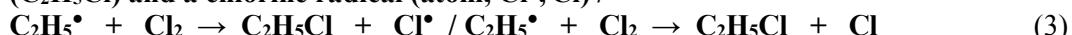
chain reaction occurs / propagation steps repeat until one reactant used up / propagation steps repeat until termination reached   (3)
[Accept 'chain reaction occurs' anywhere in (*c*).]

termination:
combination of remaining radicals to form molecules (chlorine, chloroethane, butane) /
$$2Cl^\bullet \rightarrow Cl_2 \;/\; 2Cl \rightarrow Cl_2 \;/$$
$$Cl^\bullet + C_2H_5^\bullet \rightarrow C_2H_5Cl \;/\; Cl + C_2H_5^\bullet \rightarrow C_2H_5Cl \;/$$
$$2C_2H_5^\bullet \rightarrow C_4H_{10} \qquad (3)$$
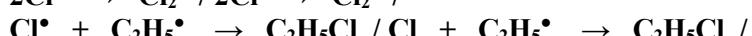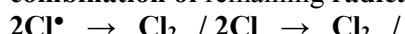
      EXPLAIN: tetraethyllead **increases the rate (speeds up** reaction) by **providing (producing, breaking into)** ethyl free **radicals** /
                    tetraethyllead increases **initiates (promotes)** reaction by **providing (producing, breaking into)** ethyl free **radicals**   (3)
                    ['Radical promoter' insufficient on its own.]

(*d*)   NAME: **ethyl methanoate / ethyl formate**   (3)

DRAW: (6)
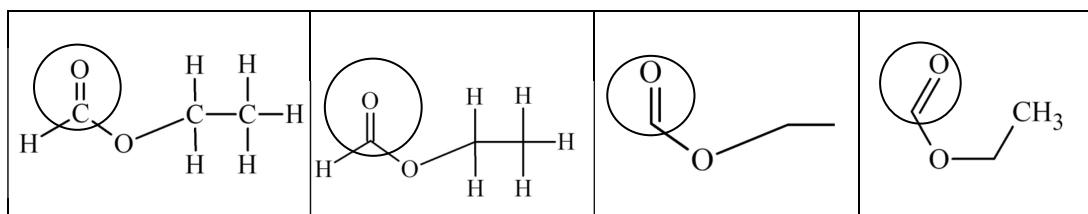
Note some or all of the hydrogens and carbons need not be shown explicitly; -C$_2$H$_5$ need not be expanded; allow -Et instead of -C$_2$H$_5$; accept HCOOC$_2$H$_5$] [NAME and DRAW not linked.]

CIRCLE: *only the carbonyl group circled*   (3)
[Allow carbonyl identified in incorrect **ester**.]

WHAT: base **hydrolysis** / **saponification**   **(2)**

QUESTION 9

(*a*) (*i*) UNDER: **20 °C //**
in the dark (2×3)
[Allow 19-21 °C.]

(*ii*) AFTER: **five (5) days**   (3)

(*iii*) DEFINE: over **enrichment** of water **with nutrients (nitrates, phosphates) / excessive**
nutrients (nitrates, phosphates) in water   (3)

STATE: excessive (abundant, dense) **plant growth / algal bloom (growth) / decreases** water
transparency / oxygen depletion (hypoxia) / fish kill / shellfish poisoning / water
colour (taste, smell, aesthetic value, value as source of drinking water supply,
value for leisure activities) impaired, etc   (3)

(*iv*) SUGGEST: **fertilizer** run-off / **silage** run-off / **slurry (wastewater, septic-tank)** run-
off / leakage from **mines** / addition of **sewage** / addition of **nitrates (phosphates,**
detergents) / **industrial pollution (waste)** / **milk (other** named **organic pollutant)**
added / **acid rain, etc**   (3)

(*b*) WHY: lead is **toxic (harmful to health, poisonous)**   (3)

NAME: **atomic absorption spectroscopy (AAS) / mass spectroscopy / gas (ionic)**
chromatography (GC) / x-ray fluorescence (diffraction, absorption) / colorimetry /
infra-red (ultraviolet, visible, IR, UV, nmr) spectroscopy / immunoassay, etc   (6)

HOW: **precipitation (ion exchange, displacement** reaction**) / distillation / reverse osmosis /**
add**ition of hydrochloric acid (HCl, lime, calcium hydroxide, CaCO₃) /**
add**ition of soluble chloride (sulfate, sulfide, phosphate, hydroxide, carbonate, Cl⁻,**
SO₄²⁻, S²⁻, PO₄³⁻, OH⁻, CO₃²⁻, etc) / activated charcoal / reed bed, etc   (3)

(*c*) HOW: **rain (water) acidic due to** dissolved **carbon dioxide (CO₂) / carbonic acid (H₂CO₃) in**
rain (water) / H₂O + CO₂ → H₂CO₃ //
rain (water) reacts with **limestone to form** soluble (dissolved) **calcium hydrogen**
carbonate {calcium ions, Ca²⁺, Ca(HCO₃)₂}
(2×3)

or

CaCO₃ + H₂O + CO₂ → Ca(HCO₃)₂ / H₂CO₃ + CaCO₃ → Ca(HCO₃)₂
(6)

(*i*) WRITE: **Ca(HCO₃)₂ → CaCO₃ + H₂O + CO₂ / Ca(HCO₃)₂ → CaCO₃ + H₂CO₃**
FORMULAE: (3) BALANCING: (3)

(*ii*) EXPLAIN: two **hydrogen ions (2H⁺)** from the **cation-exchange resin (RH) replace** a **Ca²⁺ (cations,**
positive ions) in the water / **2RH + Ca²⁺ → R₂Ca + 2H⁺ //**
a **hydroxide (hydroxyl) ion (OH⁻)** from the **anion-exchange resin (R*OH) replaces** a
HCO₃⁻ (anions, negative ions) in the water / **R*OH + HCO₃⁻ → R*HCO₃ + OH⁻**
(2R*OH + 2HCO₃⁻ → 2R*HCO₃ + 2OH⁻) //
hydrogen ion(s) (H⁺) and **hydroxide (hydroxyl) ion(s) (OH⁻) combine to form water /**
2H⁺ + 2OH⁻ → 2H₂O / H⁺ + OH⁻ → H₂O   (3 + 3 + **2**)

QUESTION 10

(*a*)   (*i*)   DISTNG: *stong acid:* **good proton donor / readily donates protons** / almost **fully dissociated //**
weak acid: **poor proton donor / slightly (poorly, weakly) dissociated**   (2 × 3)
[Allow *'Partly (partially, not fully) dissociated'* and *'does not readily donate protons'* for weak acid description.]

(*ii*)   CALCULATE: **0.005** M   (6)

> pH= –log [H$^+$] $\Rightarrow$[H$^+$] = inverse log (–2) = **0.01**   (3)
>
> 0.01 ÷ 2 (dibasic) = **0.005** M   (3)

CALCULATE: **5/9 (0.556)** M [**0.55 – 0.56 M**]   (6)

> pH= –log [H$^+$] $\Rightarrow$[H$^+$] = inverse log (–2) = **0.01**
>
> $\Rightarrow K_a$ **(1.8 × 10^{-4})** = $\frac{[H^+][A^-]}{[HA]}$ ($\frac{[H^+]^2}{[HA]}$, $\frac{(0.01)^2}{[HA]}$) / **[HA]** = $\frac{(0.01)^2}{1.8 \times 10^{-4}}$ / **[HA]** = $\frac{(0.01)^2}{K\mathrm{a}}$ /
>
> [H$^+$] = $\sqrt{K\mathrm{a}[HA]}$ / 0.01 = $\sqrt{\mathbf{1.8 \times 10^{-4}}[HA]}$ / [H$^+$]^2 = Ka[HA] / (0.01)^2 = **1.8 × 10^{-4}**[HA]   (3)
>
> [HA] = **= 5/9 (0.55555)** M   [**0.5556 – 0.56 M**]   (3)
>
> [acid] = [HA] = [HX] = M = M_a

(*iii*)   DEFINE: K_w = **[H$^+$][OH$^-$]** / K_w = **[H$_3$O$^+$][OH$^-$] / product of molar concentrations of hydrogen (hydronium) ions (H$^+$, H$_3$O$^+$) and hydroxide (hydroxyl) ions (OH$^-$) in water**   (3)

WHAT: **3.0 × 10^{-7}** M   (4)

> K_w (9.0 × 10^{-14}) = [H$^+$]^2 / [H$^+$] = $\sqrt{K_w}$ ($\sqrt{9.0 \times 10^{-14}}$) / [H$^+$] =[OH$^-$]
>
> $\Rightarrow$ [H$^+$] = **3.0 × 10^{-7}** M   **(4)**

(*b*) DEFINE: (*i*) **gain of (increase in) electrons** (3)

(*ii*) **reduction (decrease)** in oxidation number (3)

ASSIGN: $ClO^- + S_2O_3^{2-} + OH^- \rightarrow Cl^- + SO_4^{2-} + H^+$
  +1   +2   −1   +6 (3)
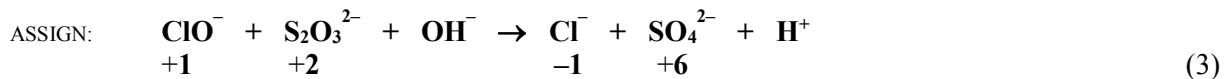
IDENTIFY: (*iii*) Reducing agent: $S_2O_3^{2-}$ / S^{2+} / S(+2) /S(2) / S(II) /

sulfur (S) in +2 oxidation state / sulfur (S) in $S_2O_3^{2-}$ (3)

(*iv*) Oxidising reagent: **ClO^- / Cl^+ / Cl(+1) / Cl(1) / Cl(I) /**

chlorine (Cl) in +1 oxidation state / chlorine (Cl) in ClO^- (3)
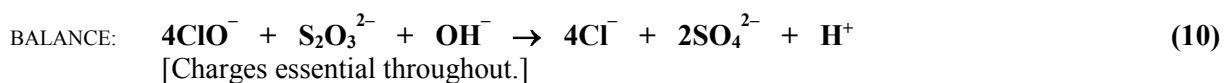
BALANCE: $4ClO^- + S_2O_3^{2-} + OH^- \rightarrow 4Cl^- + 2SO_4^{2-} + H^+$ **(10)**
[Charges essential throughout.]

Where 10 marks not awarded for the balanced equation
$4ClO^- + S_2O_3^{2-} + OH^- \rightarrow 4Cl^- + 2SO_4^{2-} + H^+$
award 3 marks for sulfur balanced and 3 marks for chlorine balanced.
[Charges essential throughout.]

or

$ClO_3^- + 6Br^- + 6H^+ \rightarrow Cl^- + 3Br_2 + 3H_2O$ **(10)**
[Charges essential throughout.]

Where10 marks not awarded for the balanced equation
$ClO_3^- + 6Br^- + 6H^+ \rightarrow Cl^- + 3Br_2 + 3H_2O$
award 3 marks for bromine balanced and 3 marks chlorine balanced.
[Charges essential throughout.]
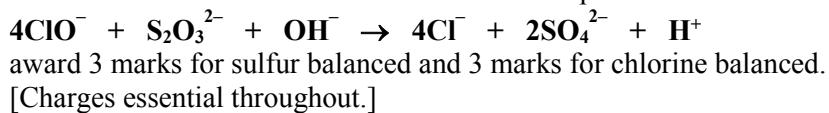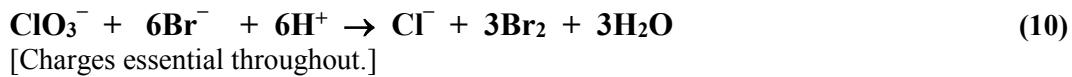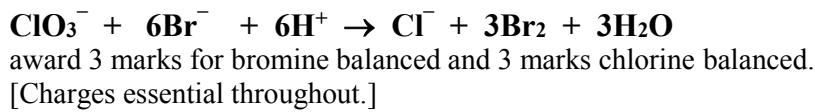
Award marks for one equation only.

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

WHAT: isotope (atom) with **unstable nucleus / nucleus (isotope)** spontaneously **decays**
(decomposes, emits radiation, emits alpha, beta and gamma **rays) / radioactive**
isotope   (3)

DEFINE: **time** taken //
for half the sample **to decay (decompose) / for activity to reduce by (to) a half**
    (2 × 2)

(*ii*)   COMPLETE: $^{222}_{86}\text{Rn}$ // $^{4}_{2}\text{He}$ (2 × 3)

(*iii*)   HOW
MANY: **7.5 × 10^{18}** atoms of radium–223   (6)

$\frac{1 \times 10^{-4} \times 12.5}{100}$ = **1.25 × 10^{-5}** moles radium–223 left   (3)

1.25 × 10^{-5} × 6.0 × 10^{23} = **7.5 × 10^{18}** atoms of radium–223   (3)

or

1.0 × 10^{-4} × 6.0 × 10^{23} = **6.0 × 10^{19}** atoms of radium–223 initially   (3)

$\frac{6 \times 10^{19} \times 12.5}{100}$ = **7.5 × 10^{18}** atoms radium–223 left   (3)

or

$\frac{1 \times 10^{-4} \times 87.5}{100}$ = 8.75 × 10^{-5} moles radium–223 decayed

1.0 × 10^{-4} – 8.75 × 10^{-5} = **1.25 × 10^{-5}** moles radium–223 left   (3)

1.25 × 10^{-5} × 6.0 × 10^{23} = **7.5 × 10^{18}** atoms of radium–223   (3)

or

1.0 × 10^{-4} × 6.0 × 10^{23} = **6.0 × 10^{19}** atoms of radium–223 initially   (3)

$\frac{6 \times 10^{19} \times 87.5}{100}$ = 5.25 × 10^{19} atoms radium–223 decayed

6.0 × 10^{19} – 5.25 × 10^{19} = **7.5 × 10^{18}** atoms radium–223 left   (3)

QUESTION 11

(*a*) (*i*) WHICH: **sulfur (S)** **(1)**

WHAT: **16** g S (12)

$$\frac{20.2}{101^*} = \textbf{0.2} \text{ moles KNO}_3 \quad (3)$$

$$\frac{24.0}{32} = \textbf{0.75} \text{ moles S} \quad (3)$$

and

$\frac{0.2 \times 5}{4} = \textbf{0.25}$ moles S required to react with 0.2 moles KNO$_3$ **(2)**

$0.75 - 0.25 = \textbf{0.5}(0)$ moles S unused (in excess) **(2)**

$0.5 \times 32 = \textbf{16}$ g S unused **(2)**

or

$\frac{0.75 \times 4}{5} = 0.6(0)$ moles KNO$_3$ required to react with 0.75 moles S

$\Rightarrow 0.2$ moles KNO$_3$ limiting

$\frac{0.2 \times 5}{4} = \textbf{0.25}$ moles S required to react with 0.2 moles KNO$_3$ **(2)**

$0.75 - 0.25 = \textbf{0.5}(0)$ moles S unused (in excess) **(2)**

$0.5 \times 32 = \textbf{16}$ g S unused **(2)**

or

$\frac{0.2}{4} < \frac{0.75}{5}$ / $0.05 < 0.15$ $\qquad \Rightarrow 0.2$ moles KNO$_3$ limiting

$\frac{0.2 \times 5}{4} = \textbf{0.25}$ moles S required to react with 0.2 moles KNO$_3$ **(2)**

$0.75 - 0.25 = \textbf{0.5}(0)$ moles S unused (in excess) **(2)**

$0.5 \times 32 = \textbf{16}$ g S unused **(2)**

(*ii*) CALCULATE: **7.84** litres (6)

$\frac{0.2 \times 7}{4} / \frac{0.2 \times 2}{4} + \frac{0.2 \times 5}{4} = \textbf{0.35}$ moles gas (3)

$0.35 \times 22.4 = \textbf{7.84}$ litres (3)

[Award final answer of **2.24** litres **and 5.60** litres (5)]
[*Use of 24 L as molar volume not acceptable here.*]

WHAT: **9.4** g K$_2$O (6)

$\frac{0.2 \times 2}{4} = \textbf{0.1}$ moles K$_2$O (3)

$94^* \times 0.1 = \textbf{9.4}$ g K$_2$O (3)

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

(*b*) DETERMINE: **pure covalent / non-polar** covalent   **(4)**
                    [Accept **slightly polar** covalent.]

DRAW:
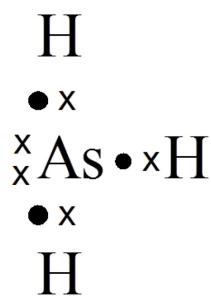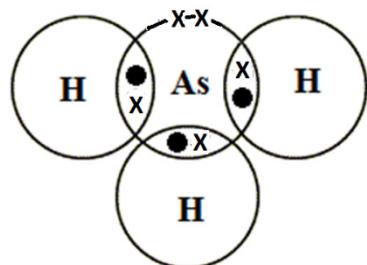
(6)

PREDICT: **pyramidal (trigonal pyramidal)**   (3)
          [No marks for 'trigonal' on its own.]
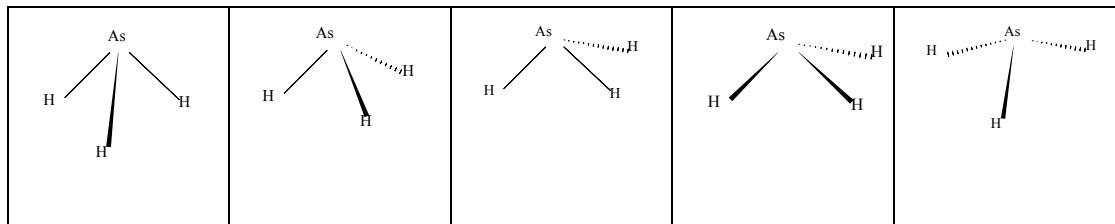
[Diagram insufficient unless a 3d representation using at least one wedge or dash, as shown.]

WHICH: **azane / ammonia / NH$_3$**   (3)
JUSTIFY: **nitrogen (N) small and** strongly **electronegative** / hydrogen bonds occur when
           hydrogen is bonded to nitrogen, oxygen, fluorine **(N,** O, F)   (3)
           [JUSTIFY marks only available if WHICH marks awarded.]

SUGGEST: (*i*)   **hydrogen bonding** in azane (ammonia, NH$_3$) **stronger** than the other
                   intermolecular forces (dipole-dipole, van der Waals) in phosphane or arsane /
                   hydrogen bonding strongest type of intermolecular force //   (3)
           (*ii*) **phosphine (PH$_3$) molecules smaller (lighter, smallest** of the two**)** /
                   phosphine (PH$_3$) molecules have smaller (smallest of the two**) molecular mass /
                   phosphine (PH$_3$) has fewer (fewest** of the two**) electrons / phosphine
                   (PH$_3$) has a smaller (smallest** of the two**) degree of intermolecular (van der
                   Waals) forces**   (3)
                   [Accept equivalent phrases with respect to arsine (AsH$_3$)]

(*c*) **A** (*i*) WHAT: **absorbs {shields** earth (us) **from}** ultraviolet (uv) radiation   **(4)**

    (*ii*) HOW: **high energy {frequency (short wavelength)} radiation / ultraviolet (uv)**
radiation / **UVC //**
breaks oxygen molecules (O_2) into separate **atoms (radicals) /**
$O_2 \rightarrow 2O / O_2 \rightarrow 2O^{\bullet}$ //
these **oxygen atoms (O, $O^{\bullet}$, radicals) react with oxygen molecules (O_2) to form**
ozone (O_3) / O + O_2 $\rightarrow$ O_3 / $O^{\bullet}$ + O_2 $\rightarrow$ O_3 (3×3)

    (*iii*) DESCRIBE: **Cl + O_3 $\rightarrow$ ClO + O_2 / $Cl^{\bullet}$ + O_3 $\rightarrow$ $ClO^{\bullet}$ + O_2 //**
ClO + O $\rightarrow$ Cl + O_2 / $ClO^{\bullet}$ + $O^{\bullet}$ $\rightarrow$ $Cl^{\bullet}$ + O_2 //
chain reaction / process repeats (continues) / Cl ($Cl^{\bullet}$) attacks another O_3
(ozone molecule**) / repeat line 1** (3×3)
[Radical dots not essential here.]

    (*iv*) WHY: **broken down before they reach stratosphere / broken down more easily** than
CFCs / **broken down in troposphere / shorter** atmospheric **residence times /**
more reactive than CFCs / **less stable** than CFCs / **CH bonds break before CF or**
CCl bonds in free radical reactions   (3)

    B (*i*) GIVE: **sodium (Na) used in street lighting (lasers, fireworks, desiccant, drying**
agent, coolant in nuclear reactors //
chlorine used to disinfect (kill microorganisms) /
chlorine used in water treatment (purification) / chlorine used as oxidising
reagent (agent) / chlorine used in making plastics (PVC, polyvinylchloride,
polychloroethene) (2×3)

    (*ii*) WHY: molten sodium chloride **conducts electricity / solid** sodium chloride **cannot**
(does not) conduct electricity   (3)

         HOW: **lowers melting point (melting temperature)** of electrolyte / **lowers the**
electrolysis temperature / fluxing agent   (3)

    (*iii*) WHAT: **to prevent recombination of** the **products / to keep products separate / to keep**
sodium (Na) and chlorine (Cl_2) separate   (3)

    (*iv*) WRITE: **$Na^+ + Cl^- \rightarrow Na + \frac{1}{2}Cl_2$ / $2Na^+ + 2Cl^- \rightarrow 2Na + Cl_2$ /**

$NaCl \rightarrow Na + \frac{1}{2}Cl_2$ / $2NaCl \rightarrow 2Na + Cl_2$

                                                           FORMULAE: (3) BALANCING: (3)

    (*v*) WHY: aluminium also **electropositive** / aluminium **high up (in) electrochemical series /**
chemical **reducing agents not strong enough** to reduce aluminium ore /
aluminium ore **not easily reduced**   **(4)**

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