Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2015

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.

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*) EXPLAIN: reaction with **potassium iodide (KI)** / reaction with **iodide (I^-)** / $I_2 + I^-$ **(KI)** / forms **soluble (dissolves as) potassium triiodide (KI_3)** / forms **soluble (dissolves as) triiodide (I_3^-)** / $\rightleftharpoons I_3^-$ **(KI_3)** (6)

(*b*) DESCRIBE: pour some **iodine (solution) in**to **a clean, dry beaker** //
use **pipette** //
previously **rinsed with deionised (distilled) water** //
rinsed with iodine (solution) //
fill using pipette filler **until bottom of meniscus is on mark** //
read at eye-level / allow drainage time / last drop to remain (not to be shaken out, blown out) / drain under gravity / touch (tip, tap) pipette **against** wall of conical **flask**
ANY THREE: $(6 + 3 + 3)$

(*c*) NAME: **starch** (3)

AT WHAT: when colour in conical flask **is light (pale) yellow (straw yellow, straw coloured)** / **close to** the **end point** / when **nearly all iodine used up** (3)

STATE: **blue-(black, navy) to colourless** (3)

(*d*) CALCULATE: (*i*) **0.00125 (1.25 × 10⁻³) moles** (6)

$$M = \frac{6.35 \times 2}{254^*} = 0.05 = \textbf{0.05}\ \text{M} \quad (3)$$

$$\frac{25 \times 0.05}{1000} = \textbf{0.00125}\ \text{moles} \quad (3)$$

/

$$\frac{6.35}{20} = \textbf{0.3175}\ \text{g in 25 cm}^3 \quad (3)$$

$$\frac{0.3175}{254^*} = \textbf{0.00125}\ \text{moles} \quad (3)$$

/

$$\frac{6.35}{254^*} = \textbf{0.025}\ \text{moles} \quad (3)$$

$$\frac{0.025}{20} = \textbf{0.00125}\ \text{moles} \quad (3)$$

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

(*ii*) **0.0025 (2.5 × 10⁻³) moles** (3)

$$0.00125 \times 2 = 0.00250 = \textbf{0.0025}\ \text{moles} \quad (3)$$

(*iii*) **0.14** M (6)

$$\frac{0.0025}{17.85} = 0.000140 = \textbf{0.000140}\ \text{moles / cm}^3 \quad (3)$$

$$0.000140 \times 1000 = 0.140 = \textbf{0.140}\ \text{M} \quad (3)$$

/

$$\frac{17.85 \times M}{2} = \frac{25 \times 0.05}{1} \quad (3)$$

$$M = 0.140 = \textbf{0.140}\ \text{M} \quad (3)$$

(*iv*) **35** g / L [**34.7 – 35** g / L] (3)

$$0.140 \times 248^{**} = 34.72 = \textbf{35}\ \text{g / L} \quad [\textbf{34.7 – 35}\ \text{g / L}]$$

[***Addition must be shown for error to be treated as slip*]
[*1 mark to be deducted for incorrect rounding off resulting in candidate's final numerical answer lying outside given values or given range but deduction to be made once only.*]

(*e*) EXPLAIN: **deionised water could contain non-ionic substances** that could be oxidised or reduced / **deionised water could contain chlorine** oxidising reagent / **deionised water** has had **only ions removed** **(5)**
[(5) allowed for '*distilled water is pure (purer, contains less impurities, contains no dissolved substances)*' or '*deionised water is less pure (contains more impurities, contains dissolved substances)*'.]['*Deionised water contains no ions*' is not acceptable.]

QUESTION 2

(*a*) DESCRIBE: **colourless** / pale **yellow (clear)** / **oily** / **liquid**   **(5)**
[*'Clarified'* not acceptable for colourless, etc; *'solution'* or *'solid'* not acceptable for liquid but cancellation does not apply.]

(*b*) STATE: **purple (violet, puce)** //
dark **brown (muddy, black)**   (2 × 3)

IDENTIFY: A = **HCl** / hydrochloric acid //
B = Na$_2$**SO$_3$** / sodium **sulfite**   (2 × 3)
[*(3) allowed for both reagents given in reverse order.*]
[*'Concentrated ethanoic acid' acceptable for A. Other acids not acceptable.*]

WHAT: dark **brown (muddy, black) disappears (dissolves)** / mixture **decolourises (becomes clear, clarifies, becomes colourless)** //
white **crystals (precipitate) form (appear, observed)**   (2 × 3)

STATE: **7 / +7 / VII / Mn^{7+} to 4 / +4 / IV/ Mn^{4+}//
4 / +4 / IV / Mn^{4+} to 2 / +2 / II / Mn^{2+}**   (2 × 3)
[*7 to 4 to 2 or equivalent acceptable for* (6).]
[*7 to 2 or equivalent acceptable for* (3).]

(*c*) STATE: **use (dissolve in) minimum amount of boiling (hot) solvent (water)** / **cool** fully / **place in ice (under cold** running **water, under cold tap)** before collecting crystals / **avoid crystallisation during hot filtration** / **use stemless funnel (hot glassware*)** for hot filtration / **use fluted filter paper** for hot filtration   (3)
[**Hot glassware includes '<u>hot Buchner funnel</u>'; 'cold Buchner funnel' unacceptable but does not cancel.*]

HOW: m.p. **raised** / **closer to 122 (119 -123)** °C /
m.p. range **sharper (narrowed, smaller)**   (6)
[*'Lower' alone or references to boiling point not acceptable.*]

(*d*) CALCULATE: **58% [57.69 – 58%]**   (12)

$2.7 \times 1.04 = \textbf{2.808}$ g (3)	$2.7 \times 1.04 = \textbf{2.808}$ g (3)
$\frac{2.808}{108^*} = \textbf{0.026}$ moles (3)	$\frac{2.808}{108^*} = \textbf{0.026}$ moles (3)
$0.026 \times 122^{**} = \textbf{3.172}$ g (3)	$\frac{1.83}{122^{**}} = \textbf{0.015}$ moles (3)
$\frac{1.83}{3.172} \times 100 = \textbf{58}\%$ **[57.69 – 58%]** (3)	$\frac{0.015}{0.026} \times 100 = \textbf{58\%}$ **[57.69 – 58%]** (3)

[**Addition must be shown for error to be treated as slip.*]
[***Addition must be shown for error to be treated as slip.*]
[*1 mark to be deducted for incorrect rounding off resulting in candidate's final numerical answer lying outside given values or given range but deduction to be made once only.*]

QUESTION 3

(*a*) DESCRIBE: **known volume** of water sample //
through filter paper //
of known mass / through weighed filter paper //
dry* filter paper / **place in oven (on radiator, etc)** //
find new **mass of filter paper** and residue / **reweigh filter paper** and residue

ANY FOUR: (4 × 3)

(*b*) CALCULATE: **0.35** g / 250 cm³ (6)

1400 ppm = 1400 mg / L = **1.4** g / L (3) 1.4 ÷ 4 = **0.35** g / 250 cm³ (3)	1400 ppm = 1400 mg / L ⇒ **350** mg / 250 cm³ (3) 350 ÷ 1000 = **0.35** g / 250 cm³ (3)

[*1 mark to be deducted for incorrect rounding off.*]

(*c*) WHAT: **EDTA (edta) / ethylenediaminetetraacetic acid** (6)

SUGGEST: **temporary hardness removed** / **only permanent hardness remaining** /
precipitate of carbonate (CO_3^{2-}) formed by boiling and removed by filtration /
soluble hydrogencarbonate (HCO_3^-) removed as (converted to) solid (precipitate,
insoluble compound) by boiling /

$$Ca(HCO_3)_{2\,(aq)} \xrightarrow{\text{boiling}} \quad / \quad \xrightarrow{\text{boiling}} CaCO_3{\downarrow} + H_2O + CO_2$$

(3)
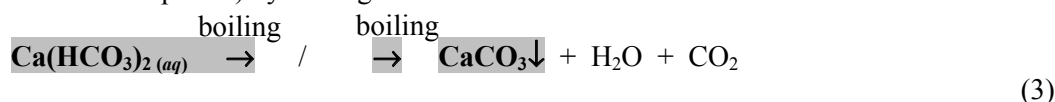
[*Half equations above with $Mg(HCO_3)_2$ or HCO_3^- acceptable in place of $Ca(HCO_3)_2$.*]

(*d*) IDENTIFY: **DPD (diethylphenylenediamine) / KI (potassium iodide, I^-) and H^+ (acid)** (6)

DESCRIBE:

Comparator		Colorimeter	
add reagent (tablet, sachet) to sample in suitable container (compartment of comparator)	(3)	**prepare** a number of **standard solutions of reagent**	(3)
stir (dissolve, mix, allow time, wait) for colour to develop	(3)	**take (note) colorimeter readings (absorbances, transmittances,** colour **intensities)**	(3)
compare colour with chart (disc, card, comparator display**)**	(3)	**plot graph of concentration versus reading (absorbance, transmittance,** colour **intensity)**	(3)
read (match, get, note) concentration (ppm) of free chlorine (by reference to) chart (disc, card, comparator display)	(3)	**read (get, note) concentration (ppm)** of sample from graph (curve) using sample absorbance	(3)

[*Marks available for description where method incorrectly named.*] ANY THREE: (3 × 3)

(*e*) WHICH: free **chlorine** **(2)**

WHAT: (*i*) **infection (disease) / microorganisms (pathogens, bacteria, germs, fungi, athlete's foot, ringworm** present / more **viruses (warts, verrucae)** present (3)
['*Hazard*', '*health problems*', '*dangerous*' are unacceptable.]

(*ii*) **taste** impaired / unpleasant **smell / nausea / eye (skin) irritation / skin burning / breathing problems (swimmers' asthma)** / formation of harmful **chloramines (compounds containing nitrogen and chlorine) / toxic (poisonous, harmful, irritating)** effects of high chlorine concentrations (levels) (3)

QUESTION 4

Eight items to be answered. Six marks to be allocated to each item and one additional mark to be added to each of the first two items for which the highest marks are awarded.

(*a*) HOW MANY: (*i*) **10** //
(*ii*) **14** (2 × 3)

(*b*) EXPLAIN: **average of** mass numbers of the **isotopes** of an element /
average mass of all (an) **atom**(s) of an element (6)
[Explanations based on sub-atomic particles not having masses that are in whole
amu or stating that the exact masses of the neutron and proton differ may be acceptable.]

(*c*) WHAT: **a neutron changes into a proton /** $_0^1n \rightarrow\ _1^1p$ //
and **an electron (+** e^-**) that is emitted** (2 × 3)
['*Proton (atomic) number increases by one*' is allowable for (3) if no other mark awarded.]
['*Beta-particle emitted*' is not acceptable.]
[Accept for (6) '*a positron is emitted when a proton changes into neutron*'.]

(*d*) ACCOUNT: **boron [central atom of boron trifluoride (BF₃)] has three bond pairs** of electrons //
nitrogen [central atom of ammonia (NH₃)] has three bond pairs and one lone pair of
electrons
or
boron [central atom of boron trifluoride (BF₃)] has three valence **pairs of electrons** //
nitrogen [central atom of ammonia (NH₃)] has four valence **pairs of electrons**
or
both ammonia and boron trifluoride **have three bond pairs** of electrons //
but **ammonia (NH₃)** also **has one lone pair**
(2 × 3)

[*Marks available for good diagrams.*]

(*e*) DEDUCE: **Cu₃N** (6)

$\dfrac{19.05}{63.5}$ = 0.300 = **0.3** moles; $\dfrac{1.4}{14}$ = = 0.10 = **0.1** moles / => **3 : 1**	(3)
=> **Cu₃N**	(3)

(*f*) STATE: **equal (same) volumes of gases contain equal (same) number of particles (molecules, moles)** // **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*) (*i*) CIRCLE: **carboxylic acid** //
(*ii*) RECTANGLE: **carbonyl** (2 × 3)
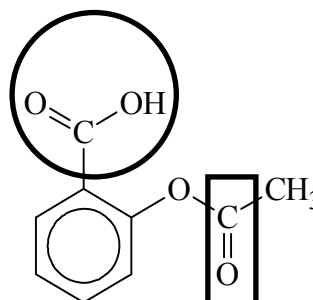
[*Unambiguous labelling acceptable instead of circle and rectangle.*]

(*h*) IDENTIFY: (*i*) **sodium (Na) //**
(*ii*) **beryllium (Be)**   (2 × 3)

(*i*) WHAT: **reduce (remove, lower) nitrates [nitrate identified by name (formula)] //**
reduce (remove, lower) phosphates [phosphate identified by name (formula)] (2 × 3)

or

to prevent (avoid) algal bloom (eutrophication) downstream   (6)

(*j*) CALCULATE: **0.005 (5 × 10⁻³) moles**   (6)

$$1.85 \times 10^5 \times 6.50 \times 10^{-5} = n \times 8.3 \times 293 \ / \ n \ = \ \frac{1.85 \times 10^5 \times 6.50 \times 10^{-5}}{8.3 \times 293}$$ (3)

$$= 0.005 \ (5 \times 10^{-3})$$ (3)

or

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \ * \ => \ \frac{1.85 \times 10^5 \times 6.50 \times 10^{-5}}{293} = \frac{1.01 \times 10^5 \times V_2}{273} \ => V_2 = 1.11 \times 10^{-4} \ \text{m}^3$$ (3)

$$\frac{1.11 \times 10^{-4}}{22.4 \times 10^{-3}} = 0.005 \ (5 \times 10^{-3}) \quad [*Using\ standard\ T\ \&\ P\ and\ molar\ volume\ at\ s.t.p.]$$
(3)

or

$$P_1V_1 = P_2V_2 ** => 1.85 \times 10^5 \times 6.50 \times 10^{-5} = 1.01 \times 10^5 \times V_2 => V_2 = 1.19 \times 10^{-4} \ \text{m}^3$$ (3)

$$\frac{1.19 \times 10^{-4}}{24.0 \times 10^{-3}} = 0.005 \ (5 \times 10^{-3}) \quad [**Using\ room\ T\ \&\ P\ and\ molar\ volume\ at\ room\ temperature.]$$
(3)

[*1 mark deducted if the answer is not correct to one significant figure.*]
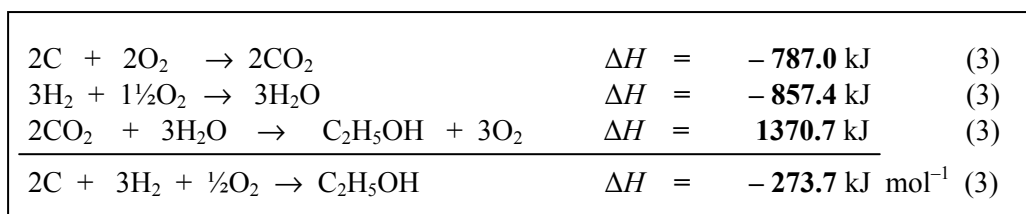
(*k*) **A** STATE: **lightning //**
nitrogen-fixing bacteria / bacteria in root nodules / (*Rhizobium*, etc) (2 × 3)
['*Thunder storms*' allowed for '*lightning*' for (3).]
['*Legumes*' (*named legume, e.g. alfalfa, clover, peas, etc*) allowed for '*bacteria in root nodules*' / (*Rhizobium*, etc) for (3).]

B WHAT: **shredding (broken into small pieces) //**
re-extrusion (re-moulding)   (2 × 3)
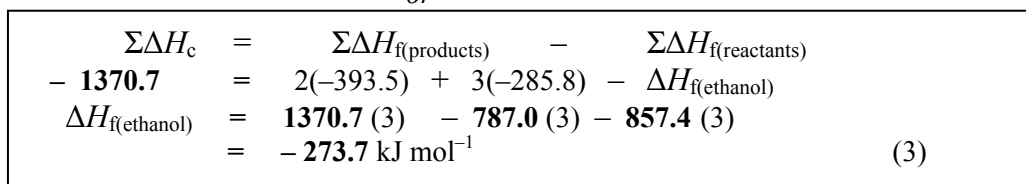
QUESTION 5

(*a*)   (*i*) GIVE: **fluorescence / glow / coloured light / shadow cast by anode (cross, object)** / deflection of beam **using magnetic (electric) field / paddle (wheel) rotated** clockwise / **paddle (wheel) pushed (moved** to) right / using a **charged electroscope** / associated **static electricity** (3)

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

            WHAT: **electron** (3)

(*b*) NAME: Henri **Becquerel** / Marie **Curie** / Pierre **Curie** (3)

(*c*) STATE: **most** alpha-particles **undeflected (passed straight through, were deflected slightly as they passed through)** the gold foil //
some alpha-particles **deflected** //
some (a few) alpha-particles **reflected (deflected** straight **back)** along their original paths
[Marks available from a good labelled diagram.] (3 × 3)

      EXPLAIN: (*i*)   **repulsion (deflection)** of positive alpha-particles (3)

               (*ii*)   **most** alpha-particles **undeflected (passed straight through, were deflected slightly as they passed through)** the gold foil /
large angles of deflection (repulsion) for many alpha-particles consistent with charge concentrated in small, dense nucleus /
a few (a small number) alpha-particles **reflected (deflected** straight **back)** showing most of mass concentrated in small, dense nucleus /
statistical analysis of angles of deflection consistent with charge and mass concentrated in small, dense nucleus (3)
[Marks for EXPLAIN (*i*) or (*ii*) cannot be given for STATE above.]

(*d*) EXPLAIN: **in the ground state the** hydrogen **electron occupies the lowest** available **energy level //**

                the electron can jump (move, become excited) to a higher energy **level (state) if it receives (absorbs)** a certain amount of **energy (light, heat, electricity, a photon) //**

                excited (higher energy**) state unstable (temporary) //**

                electron falls back to a lower level   ANY THREE: (3 × 3)

                energy emitted (given out) as photon (light of definite frequency, light of definite wavelength, hf, $h\upsilon$) thus giving rise to a spectrum /

                energy emitted (hf, $h\upsilon$) corresponds to (=) difference between the **two energy levels ($E_2 - E_1$)** thus giving rise to a line on the spectrum / $E_2 - E_1 = hf$ ($h\upsilon$) (3)
[Marks not awarded wherever '*atom*' is incorrectly used instead of '*electron*'.]
[Some marks, maximum (6), available from a good labelled diagram.]

(*e*) SUGGEST: **copper** ['*Barium*' or '*boron*' acceptable.] (3)

(*f*) WRITE: **$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2$ / [Ar]$4s^2$** **(5)**
[*Subscripts instead of superscripts acceptable.*]
[*Arrows to represent numbers of electrons acceptable but orbital symbols must be given.*]

      GIVE: **energy (distance to nucleus) of 2s electron less than 3s/**
nuclear attraction for 2s electron greater than 3s /
2s electron less shielded (screened) than 3s from nucleus /
energy for ionisation (removal of electron) of (from) 2s greater than for 3s /
probability distribution (volume, size) of 2s less than 3s **(3)**
[Corresponding statements given with regard to **3s** are equally acceptable.]

QUESTION 6

(*a*) IDENTIFY: relative **molecular mass / boiling (condensing) point (temperature) / size of molecules / number of carbons (carbon atoms)** / extent of **intermolecular (van der Waals) forces (attractions)** **(5)**

['*Length of carbon chain*' is not acceptable.]['*Temperature*' on its own not acceptable.]

(*b*) (*i*) NAME: **kerosene (kerosine, paraffin)** (3)

(*ii*) WHAT: catalytic **cracking** (3)

(*c*) WHAT: **heptane / n-heptane / $CH_3(CH_2)_5CH_3$ //**
2,2,4-trimethylpentane (*iso*octane) / $(CH_3)_3CCH_2CH(CH_3)_2$ (2 × 3)
[Accept structures but not C_7H_{16} or C_8H_{18}.]

(*d*) GIVE: **increases octane number (rating) / reduces knocking (pinking, pre-ignition) //**
reduces pollution / less negative environmental impact / less harm to environment / greener (cleaner, eco-friendly) fuel **/ cleaner burn** of fuel **/ more complete combustion / lowers carbon monoxide** emission **/ lowers** emission of **carbon (soot)** particles **/ lowers** emission of poly**aromatics / eliminates** need for **lead** compounds **/ emissions less toxic**
(2 × 3)

(*e*) CALCULATE: **– 273.7** kJ mol^{-1} (12)

$2C + 2O_2 \rightarrow 2CO_2$	ΔH =	**– 787.0** kJ	(3)
$3H_2 + 1\frac{1}{2}O_2 \rightarrow 3H_2O$	ΔH =	**– 857.4** kJ	(3)
$2CO_2 + 3H_2O \rightarrow C_2H_5OH + 3O_2$	ΔH =	**1370.7** kJ	(3)
$2C + 3H_2 + \frac{1}{2}O_2 \rightarrow C_2H_5OH$	ΔH =	**– 273.7** kJ mol^{-1}	(3)

or

$$\Sigma\Delta H_c = \Sigma\Delta H_{f(products)} - \Sigma\Delta H_{f(reactants)}$$
$$-\mathbf{1370.7} = 2(-393.5) + 3(-285.8) - \Delta H_{f(ethanol)}$$
$$\Delta H_{f(ethanol)} = \mathbf{1370.7}\,(3) - \mathbf{787.0}\,(3) - \mathbf{857.4}\,(3)$$
$$= \mathbf{-273.7}\ \text{kJ mol}^{-1} \qquad (3)$$

[Where $787.0 + 857.4 – 1370.7 = + 273.7$ is given there *may* be justification for award of up to 9 marks, e.g. if explained by reversed equations. $+ 273.7$ is worth only 3 marks if it is associated with the equations as written above.]
[*1 mark deducted for incorrect rounding off.*]

(*f*) (*i*) GIVE: **light / low density / low molecular mass //**
high energy content per kilogram (unit mass) / high kilogram **calorific value (heat of combustion) / high octane number (rating) / powerful (efficient) //**
minimally (non-) polluting (cleaner, green**er, eco-friendly) / only product** of combustion is **water** ANY TWO: (2 × 3)

(*ii*) STATE: **leaks easily** out of containers **/ explosive / difficult to liquefy / low energy content per litre (unit volume) / difficult to pipe (store, transport) / hazardous (dangerous) / expensive** (3)

(*iii*) GIVE: **steam reforming** of natural gas (methane, CH_4, hydrocarbons**) //**
dehydrocyclisation (reforming) //
electrolysis of water (H_2O) **/ electrolysis** of brine (NaCl solution) **//**
co-product (by-product) of catalytic **cracking //**
coal gasification / from coal //
decomposition of water gas (mixture of CO and steam) ANY TWO: (2 × 3)
[*Equations acceptable.*]

QUESTION 7

(*a*) WHAT: substance that **alters (changes) rate of a reaction //**
but **not consumed (used up, chemically changed)** in the reaction
[Allow '*speeds up*' or '*slows down*' in place of '*alters rate*'.]

or

substance that **provides alternative (different) pathway for reaction //**
that has (with) different (higher, lower) activation energy **(3 + 2)**

(*b*) EXPLAIN: **ionic** compounds react **quickly (**almost **instantaneously)** in solution **as dissociated
(ions free, ions** only need to **collide)** / **ionic** compounds react **quickly (**almost
instantaneously) in solution **as lattice (bonds)** already **broken** /
covalent compounds react **slowly as bonds need to be broken** first (before reaction, to
initiate reaction) / (6)
['*Ionic react quickly, covalent react slowly*' - allow 3; '*Ionic faster, covalent slower*' not
acceptable.]

HOW: **lowering the temperature (cooling) / lowering the concentration (diluting) /
inhibitor (negative catalyst)** (3)
['*Absence (lower concentration, lower surface area, larger particle size,
smaller amount) of catalyst*' or '*changing the solvent*' are acceptable.]

(*c*) STATE: **wire glows** and dims / **odour (smell) of methanol (HCHO, formaldehyde) / popping**
sounds / **explosions / flask becomes hot / methanol boils (bubbles) / methanol used up /
volume methanol decreases / flame (flash) / cardboard ignites** (3)

IDENTIFY: **methanal (formaldehyde, HCHO) // water (H_2O) // hydrogen (H_2)** ANY TWO: (2 × 3)
['*Methanoic acid*' unacceptable but does not cancel.]

(*d*) WHAT: **adsorption / chemisorption**
['*Absorbtion*' or '*adsorbtion*' or '*adsorbance*' are allowable.] (3)

EXPLAIN: methanol **bonds weakened (stretched, loosened) / lower activation energy / higher**
methanol **concentration** on surface / **methanol (molecules) closer together** on surface /
active sites on surface **occupied by methanol (molecules) / methanol forms temporary
(weak) bonds** on surface / **methanol (molecules) oriented correctly** for reaction /
activated catalyst (compound) formed on catalyst surface / **more effective collisions**
between reactants (3)

EXPLAIN: **surface {active site(s)} occupied (blocked)** by sulfur (poison) / sulfur (poison) **bonded
{adsorbed, chemisorbed, adhered, stuck** strongly (permanently)}** to
catalyst / sulfur (poison) **unable to desorb** from catalyst (3)
['*Absorbed*' is acceptable.]

(*e*) EXPLAIN: **minimum** combined **energy of colliding particles (molecules) //**
for reaction to take place between them

or

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

SKETCH: *y*-axis **energy,** *x*-axis **time (reaction
progress)** (3)
**suitable curve with energy of reactants
greater than energy of products** (3)
Δ*H* (between reactant and product energies) (3)
E_A (between reactant energy and peak) (3)
['*Reaction*' with an arrow is acceptable
to label *x*-axis.]
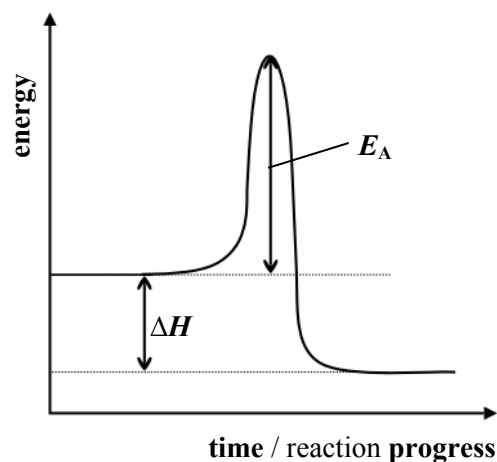
QUESTION 8

(*a*) GIVE: **A = propene / prop-1-ene**
B = 2-propanol / propan-2-ol
C = propanone / propan-2-one

$(3 + 3 + \mathbf{2})$

(*b*) NAME: **poly(propene) / polypropylene** [*'Polypropene'* is acceptable.] (3)

(*c*) IDENTIFY: *broken:* **C to O pi (π)** bond / **(pi (π)** bond of **CO (carbonyl)** //
formed: **OH / O–H / O to H** //
formed: **CH / C–H / C to H** (3×3)
[C to O, (CO, carbonyl, double, C=O) as bond broken is acceptable.][H_2 (H-H) broken
unacceptable but does not cancel.]
[C to O, (C-O, C to OH, C-OH, COH) as a bond formed is acceptable.]
[Information given *clearly* in diagram form is acceptable.]

(*d*) NAME: *isomer*: **1-propanol / propan-1-ol / propyl alcohol** //
aldehyde: **propanal / propionaldehyde** (2×3)

DRAW: *isomer*:

//
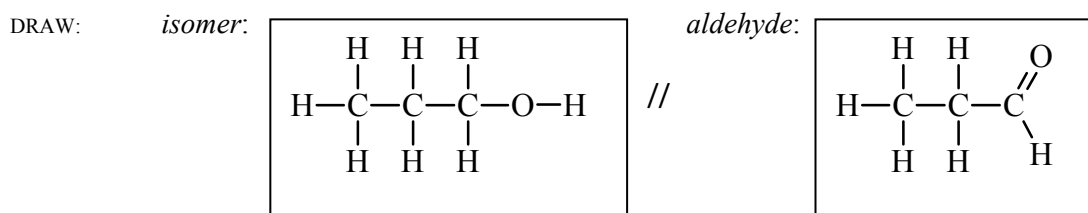
aldehyde:

(2×3)

[*Where the order in the question (isomer-aldehyde) is not followed, the identities of
the compounds must be clearly indicated.*][*-OH, -HO* for *O-H* acceptable.]

HOW: with **hydrogen (H_2)** and **nickel (Ni, platinum, Pt, palladium, Pd, ruthenium, Ru)**
catalyst / **lithium aluminium hydride (lithium tetrahydroaluminate, $LiAlH_4$)** /
sodium borohydride (sodium tetrahydroborate, $NaBH_4$) (6)
['*Reduction*' or '*hydrogenation*' acceptable for (3).]

(*e*) IDENTIFY **A (C_3H_6, propene) = – 48 $^{\circ}$C (lowest** boiling point) //

B ($CH_3CHOHCH_3$, propan-2-ol, 2-propanol) = 82 $^{\circ}$C (highest boiling point) //

C (CH_3COCH_3, propanone) = 56 $^{\circ}$C (middle boiling point) ANY TWO: (2×3)

JUSTIFY: **A (C_3H_6, propene) has van der Waals (London, dispersion, weakest dipole-dipole,
temporary, transient) forces (attractions, bonds)** between the molecules //
**B ($CH_3CHOHCH_3$, propan-2-ol, 2-propanol) has hydrogen (strongest dipole-dipole)
bonds (forces, attractions)** between the molecules //
C (CH_3COCH_3, propanone) has dipole-dipole forces (attractions, bonds) between the
molecules

CORRESPONDING TWO: (2×3)

[*The marks for* JUSTIFY *may be awarded if the answers are clearly linked
with the* **compounds** *given for* IDENTIFY.]
[*If* JUSTIFY *is given in terms of weak or strong or medium strength intermolecular forces
that are not named* (3) *may be awarded.*]

QUESTION 9

(*a*)   DEFINE: (*i*) *Arrhenius acid*: **produces H⁺ (hydrogen ion)** by dissociation **in water (aqueous solution)** //

                (*ii*) *Brønsted-Lowry acid*: **proton (hydrogen ion, H⁺) donor**   (2 × 3)

(*b*)   DEFINE: **$-\log_{10}[H^+]$ / $-\log_{10}[H_3O^+]$ / negative log** to base ten **of hydrogen (hydronium) ion concentration in moles per litre**   (6)

       STATE: **reliable (accurate, suitable)** only **for dilute solutions** / only **valid (useful)** in **0 - 14** range / **applies to aqueous solutions** only / **unreliable (inaccurate, unsuitable) in** very **concentrated solutions** / **unreliable for negative pH values**   (3)

         ['*Temperature dependent* / (*25 °C*)' acceptable.]['*Valid range 1 – 14*' unacceptable but does not cancel.]

(*c*)   GRAPH: *See graph on next page.*

              both axes correctly labelled (*pH, V, volume, cm³, NaOH*)   (3)

              appropriate, correct numeric scales on both axes   (3)

              smooth curve of correct shape corresponding to 0 -15 cm³ NaOH added and from 25- 40 cm³ NaOH added   (3)

              careful plotting of vertical part   (6)

              [*Volume versus pH* acceptable.][(3) marks deducted if graph not on graph paper.]

(*d*)   (*i*)   CALCULATE: **0.014 M [0.0139 – 0.014 M]**   (9)

$[H^+] = \sqrt{K_a[CH_3COOH]}$ / inverse log (–3.3) / **5.01 × 10⁻⁴** /

$-\log\sqrt{K_a[CH_3COOH]} = 3.3$ / $\log\sqrt{K_a[CH_3COOH]} = -3.3$ (6)

$K_a = \dfrac{[CH_3COO^-][H^+]}{[CH_3COOH]}$ / $\dfrac{[H^+]^2}{[CH_3COOH]}$ / $1.8 \times 10^{-5} = \dfrac{[5.01 \times 10^{-4}]^2}{[CH_3COOH]}$

$[CH_3COOH] =$ **0.014 M**   **[0.0139 – 0.014 M]**   (3)

Take [acid] or [HA] or *M* to be [CH₃COOH] and [A⁻] to be [CH₃COO⁻]

or

$[H^+] = \sqrt{K_a[CH_3COOH]}$ / inverse log (–3.3) / **5.01 × 10⁻⁴** /

$-\log\sqrt{K_a[CH_3COOH]} = 3.3$ / $\log\sqrt{K_a[CH_3COOH]} = -3.3$ (6)

$K_a[CH_3COOH]$ / $1.8 \times 10^{-5} \times [CH_3COOH] = (5.01 \times 10^{-4})^2$

$[CH_3COOH] = \dfrac{(5.01 \times 10^{-4})^2}{1.8 \times 10^{-5}} = \dfrac{2.51 \times 10^{-7}}{1.8 \times 10^{-5}} = \mathbf{0.014}$ **[0.0139 – 0.014 M]**   (3)

Take [acid] or [HA] or *M* to be [CH₃COOH] and [A⁻] to be [CH₃COO⁻]

    [*1 mark deducted for incorrect rounding off.*]

    (*ii*)   MAKE USE: **20 cm³**   (3)

(*e*)   WHAT: **phenolphthalein / thymol blue / cresol purple / thymolphthalein**   **(6)**

       REFER: **range** of phenolphthalein **coincides with vertical part of graph** / **range (8 -10) within pH jump** / phenolphthalein **changes colour corresponding to steep (vertical) part of graph** / phenolphthalein **changes colour within (coinciding with) pH jump** at end point / phenolphthalein **has one colour at pH = 8 (7, 6, before neutralisation, before vertical part of graph) and another at (after) pH = 10 (11, after neutralisation, after vertical part of graph)**   **(2)**

         [K_a (K_{In}, pK_a, pK_{In}) value of phenolphthalein acceptable for (4).]

         [REFER marks available only if WHAT marks awarded.]
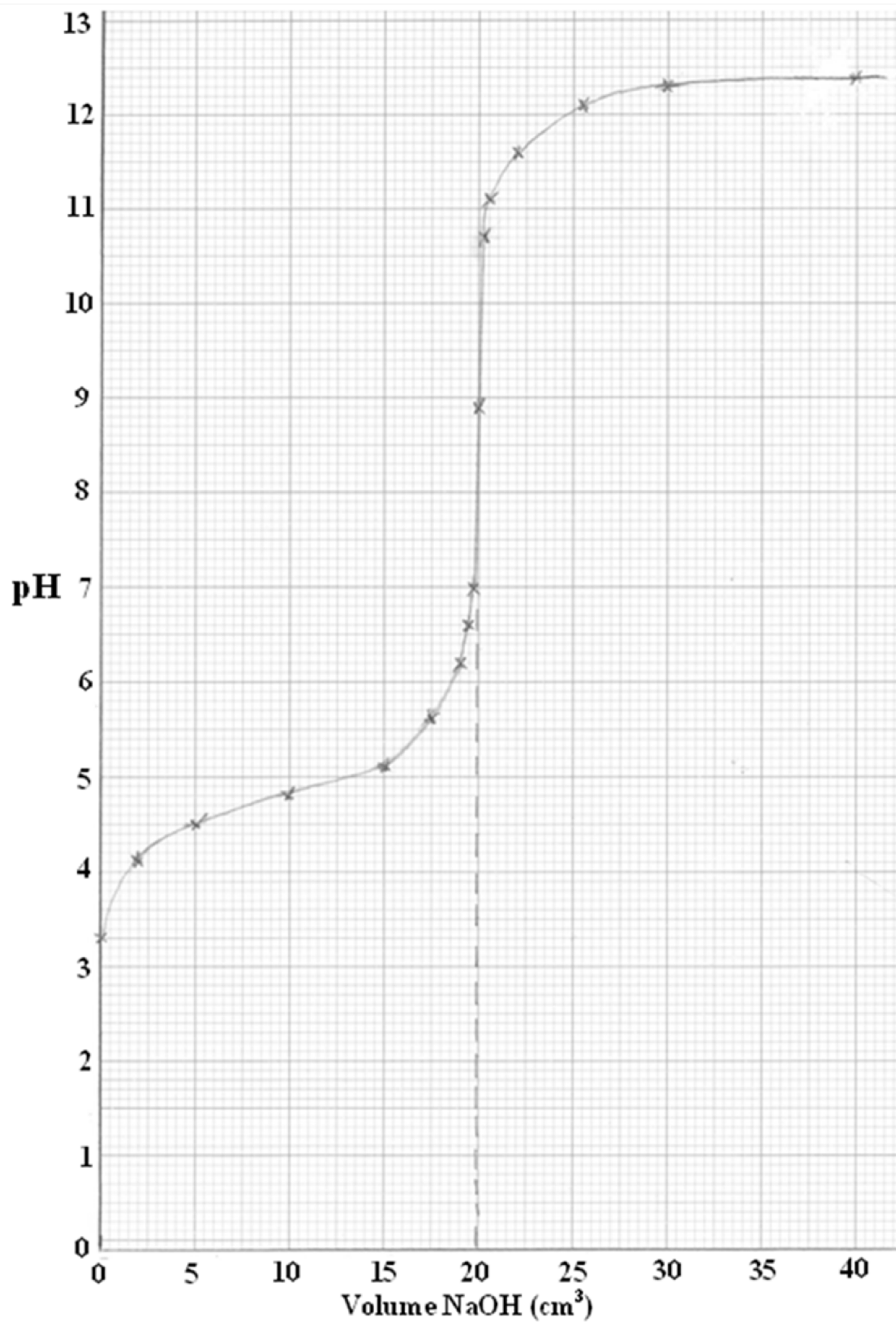
QUESTION 10

(*a*) DISTNG: saturated hydrocarbons contain **all (only) single (no double** or triple**) carbon-carbon bonds / saturated** hydrocarbons **have maximum number of hydrogen (monovalent) atoms attached** to carbon skeleton //
unsaturated hydrocarbons contain at least one **double (triple, multiple)** carbon-carbon **bond / more hydrogen (monovalent) atoms can be added** to carbon skeleton of **unsaturated** hydrocarbons   **(2 × 2)**
[*Where the order in the question is not followed, the part of the answer referring to saturation and the part referring to unsaturation must be clear.*]

DESCRIBE: **bromine (Br$_2$) solution (water) /
acidified** potassium **manganate(VII) (permanganate) / (KMnO$_4$/H$^+$) / (MnO$_4^-$/H$^+$)** (6)

decolourises (changes to colourless, colour disappears)   (3)
['*Clear*' unacceptable for '*colourless*'.]

HOW MANY: **6**   (3)

EXPLAIN: (*i*) yes, each of the **3 double bonds** has 2 pi-electrons / **each carbon has** 3 sigma and **one pi electron)**   (3)
(*ii*) **electrons** in benzene are **delocalised / electrons are in three double bonds** in the Kekulé structure /
**electrons localised in the Kekulé structure**   (3)

GIVE: all **carbon-carbon (C-C) bonds** in benzene **are of same length (energy, strength) /**
all **carbon-carbon (C-C) bonds** in benzene **are intermediate between single and double in length (energy, strength) /** chemical **stability (unreactivity)** of benzene /
no isomers of 1,2-disubstituted benzene / reacts mainly **by substitution / does not decolourise Br$_2$** solution easily / **does not decolourise acidified KMnO$_4$** solution easily / **does not undergo** electrophilic **addition**   (3)

(*b*) (*i*) EXPLAIN: **electrodes correctly labelled //
copper sulfate (soluble copper salt)** electrolyte / **battery* (power supply) //
impure copper oxidised (converted to Cu^{2+}, changed to Cu^{2+}) /** impure copper acts **as (is attached to) anode (positive electrode) //**
pure **copper** acts **as (is attached to) cathode (negative electrode) //
copper ions (Cu^{2+}) in solution reduced /** pure **copper plates** out **on cathode**
[Explanation with no diagram, max 12.][Labelled diagram alone, max 12.]
[Equations not acceptable in (i) EXPLAIN.] [*Battery terminals reversed does not cancel electrode labels.]

ANY THREE: (6 + 6 + 3)

(*ii*) WRITE: **Cu^{2+} + 2e^-→ Cu //**

Cu → Cu^{2+} + 2e^- / Cu – 2e^- → Cu^{2+}

(2 × 3)

(*iii*) WHAT: **fall to bottom** of container /
**found under anode /
anode mud (sludge)**   **(4)**
[Accept '*recovered*' or
'*used as source of valuable metals*'.]

battery

impure copper,
positive electrode,
anode, +

pure copper,
negative electrode,
cathode, –

copper(II) sulfate
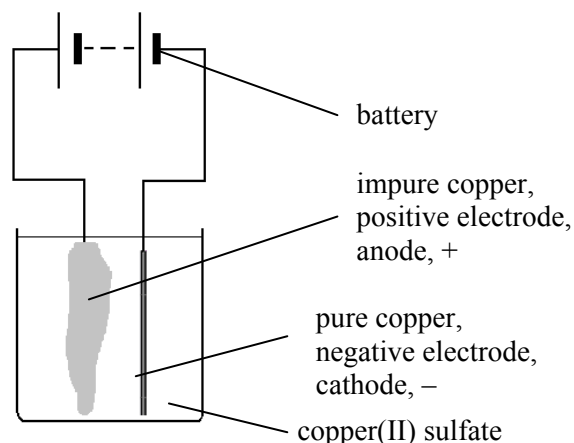
(*c*)   (*i*)   WHAT: amount containing **as many particles* as //**
the number of atoms in **0.012 kg (12 g) of carbon-12** /

or

amount containing the **Avogadro number (Avogadro constant, *L*, 6 × 10²³) //**
of **particles */**

or

amount equal to the relative **formula (molecular) mass (*M*ᵣ) //**
expressed **in grams**   (2 × 3)
[* *'Atoms', 'molecules', 'ions', 'units' for 'particles' allowed.*]

(*ii*)   HOW: **0.4 mol**   (6)

$\frac{7.6}{76^*}$ = 0.10 = **0.10** mol Mg₂Si (3)	*or*	$\frac{4 \times 24 \times 7.6}{76^*}$ = **9.6** g Mg (3)
0.10 mol Mg₂Si → 0.40 = **0.4** mol Mg (3)		9.6 ÷ 24 = **0.4** mol Mg (3)

(*iii*)   CALC: **0.4 mol**   (3)

0.10 mol Mg₂Si → 0.40 = **0.4** mol HCl   (3)   *or*

$\frac{4 \times 36.5}{76^*}$ × 7.6 = 14.6 ÷ 36.5 = **0.4** mol HCl   (3)

WHAT: **19 g MgCl₂**   (6)

0.10 mol Mg₂Si → 2 × 0.10 = **0.2** mol MgCl₂   (3)
95** × 0.20 = **19** g MgCl₂   (3)

or

76*g Mg₂Si → **2 × 95** / 190 g** MgCl₂   (3)

7.6 g Mg₂Si → 190 ÷ 10 = **19** g MgCl₂   (3)

(*iv*)   WHAT: **4.8 litres (4,800 cm³)**   **(4)**

0.10 mol Mg₂Si → 0.10 mol SiH₄ → 2 × 0.10 = **0.2** mol O₂   **(2)**
0.20 × 24 = **4.8** litres   **(2)**

or

76*g Mg₂Si → **2 × 24 / 48** L O₂   (2)

7.6 g Mg₂Si → $\frac{48}{76^*}$ × 7.6 = **4.8** L O₂   (2)

[*Use of 22.4 L as molar volume not acceptable here.*]

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

[*1 mark deducted for incorrect rounding off, once only.*]

QUESTION 11

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

WHY: **nuclear charge (number of protons, atomic number, number** of **positive** particles in
nucleus) increasing //
atomic radius decreasing   (2 × 3)

EXPLAIN: predicted the properties from properties of **known elements** / predicted the properties from
properties of **elements** in **same group (column, family)**   (6)

or

having **arranged (placed) elements in order of increasing atomic weight (mass)** /
where **elements with similar properties were arranged in columns (groups, families)** /
left gaps in his table for elements with certain properties yet to be discovered
                    (3 only)

WRITE: **GeH$_4$**   (3)

WOULD: **no //**
GeH$_4$ a **non-polar (slightly polar)** solute / **insoluble in water** like **methane (CH$_4$, silane,
SiH$_4$)**   (2 × 2)
[Second (2) only available if first (2) is awarded.]

(*b*) CALC: **50** mol   (13)

A $\leftrightharpoons$ B + C	A $\leftrightharpoons$ B + C
Start: 3.0 mol / L 0 mol / L 0 mol / L	Start: 30 mol 0 mol 0 mol
Equil**:** **(3 − x)** (3) x x (3)	Equil: (30 − x) x x
$K_c = \dfrac{(x)^2}{(3.0-x)} = 4$ (3)	Equil: $\left(\dfrac{30-x}{10}\right)$ mol / L(3) $\dfrac{x}{10}$ mol/L $\dfrac{x}{10}$ mol/L (3)
$x^2 + 4x - 12.0 = 0$	$K_c = \dfrac{\left(\frac{x}{10}\right)^2}{\left(\frac{30-x}{10}\right)} = 4$ / $\dfrac{(x)^2}{(30-x)} = 40$ (3)
$(x + 6)(x - 2) = 0$ / $x = \dfrac{-(4)\pm\sqrt{(4)^2-4(1)(-12.0)}}{2}$	$x^2 + 40x - 1200 = 0$
$x = $ **2.0 mol / L** (3)	$(x + 60)(x - 20) = 0$ / $x = \dfrac{-(40)\pm\sqrt{(40)^2-4(1)(-1200)}}{2}$
$\Rightarrow$ 5.0 mol / L total	$x = $ **20** mol (3)
$\Rightarrow$ 5.0 × 10 = **50 mol** **(1)**	$\Rightarrow$ **50 mol** total **(1)**

[Where no other mark awarded allow (3) for $K_c = \dfrac{[B][C]}{[A]}$.]

DEDUCE: **endo**thermic   (3)
EXPLAIN: **K_c increases with temperature** / at higher temperature **more products (more B and C,
more forward reaction, reaction shifts to the right, reaction opposes stress)**   (3)
[EXPLAIN marks only available if DEDUCE marks awarded.]

EXPLAIN: **increase //**
more gaseous **product (particles, B and C) / more forward reaction / equilibrium
shifts to the right / more collisions** with walls of container / **increased velocity
(energy) of** gaseous **molecules (particles) / then (followed by, resulting in)** bringing
about of **decrease {reverse, shift backward, shift left, shift to reactant(s),
shift to A}**   (2 × 3)
[Second (3) only available if first (3) is awarded.]

(c) **A** (*i*) EXPLAIN: gases that **absorb heat (energy, infra-red radiation) in atmosphere /**
gases that **retain (prevent escape of) heat (energy, infra-red radiation)** into
outer **atmosphere**   **(4)**

(*ii*) STATE: **global warming / melting** polar **ice-caps / rise in sea levels /**
flooding / wildlife endangered / wildlife **habitats endangered, etc**   (3)

(*iii*) ARRANGE: **water vapour, carbon dioxide, methane,** typical **CFC**   (6)

WHICH: **water vapour**   (3)

DESCRIBE: broken down by **ultraviolet (uv) radiation (rays, light) /**
release (give) chlorine atoms (chlorine free **radicals, Cl, Cl•)**   (3)
[*Unbalanced equation acceptable.*]

(*iv*) SUGGEST: **ban** use of **CFCs // use CFC substitutes // use HCFCs // recycle (dispose**
properly of) refrigerators (air conditioners) with CFCs // **reduce number of**
ruminants (cattle, sheep, goats, deer, etc) // collect methane gas escaping **from**
dumps (slurry) // use biogas digesters // plant more trees (avoid deforestation) //
use renewable (wind, waves, tides, solar) power (energy) // reduce fossil fuel
dependency (use) // use public transport (bus, train, etc) // walk (cycle) instead
of driving (using transport relying on fossil fuel) // use nuclear power (energy) //
etc   ANY TWO: (2×3)

B (*i*) NAME: **coke (charcoal, C, carbon) //**
limestone (CaCO$_3$)   **(2 × 2)**

(*ii*) WRITE: **Fe$_2$O$_3$ + 3CO → 2Fe + 3CO$_2$ /**
Fe$_2$O$_3$ + 3C → 2Fe + 3CO /
2Fe$_2$O$_3$ + 3C → 4Fe + 3CO$_2$ FORMULAE: (3) BALANCING: (3)

(*iii*) USE: **CaO + SiO$_2$ → CaSiO$_3$ /**
CaO + Al$_2$O$_3$ → CaAl$_2$O$_4$ {Ca(AlO$_2$)$_2$}   FORMULAE: (3) BALANCING: (3)

GIVE: **road-making / building** blocks   (3)

(*iv*) GIVE: quarrying iron ore (limestone) **damages landscape (wildlife) /** dust **reduces air**
quality / emissions of gases or dust **increases (causes) air pollution /** contributes to
global warming / carbon monoxide (CO) escape (toxicity) / noise / etc   (3)

HOW: **restore landscape / protect wildlife / filter (electrostatic removal)** dust **/ use**
scrubbers (air filtering devices) / improve efficiency / reduce heat loss /
trap (use) carbon monoxide (CO) as fuel / soundproofing / etc   (3)
[HOW marks available only if GIVE marks awarded and answers match.]

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