Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2014

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 evidence of incorrect use 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 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 attempt 8 questions in total. All questions carry equal marks (50).

Section A
At least <u>two</u> questions must be answered from this section.

Section B
At least <u>five</u> questions must be answered from this section.

Eight items to be answered in **Question 4**. Six marks 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.

Note that candidates who attempt **Question 10** are required to answer two of the parts (*a*), (*b*) and (*c*) and candidates who attempt **Question 11** are required to answer two of the parts (*a*), (*b*) and (*c*) where candidates who answer part (c) may choose **A** or **B**.

QUESTION 1

(*a*) EXPLAIN: **concentration (molarity) known (found, got, etc.) by** another **titration (colorimetry, u.v. spectroscopy)** **(5)**
[Allow 4 for **concentration (molarity) known (found, got, etc)**.]

(*b*) DISSOLVED AND MADE-UP: wash (rinse) into beaker **of deionised (distilled, pure) water //**
stir to dissolve **//**
pour through **funnel (down glass rod) into volumetric flask adding rinsings** of beaker **//**
add last few drops of deionised water **drop by drop (using dropper) to bring bottom of meniscus level with (up to, on, at) mark** reading at eye level (6 + 3 + 3)
[Stopper and invert does not ensure solution made up to exactly 250 cm^3.][‘Deionised’ mentioned anywhere in (*b*) is acceptable for first point.]

(*c*) STATE: **add drop by drop (slowly) / wash down** inner **sides of** conical **flask / swirl (shake)** flask contents **//**

EXPLAIN: add dropwise so that **end point will be precisely (accurately) detected (correct end point not passed) / one drop** of solution **would change colour near end point /**
wash sides **so that all reagent(s) (acid) in the reaction mixture /**
swirl **to ensure thorough mixing** of reactants (2 × 3)
[‘State’ & ‘Explain’ to be linked.]

(*d*) NAME: **methyl orange / methyl red / bromophenol blue / bromocresol green** (3)

CHANGE: **before // after** (2 × 3)

Name (3)	**Colour before** (3)	//	**Colour after** (3)
methyl orange	orange (yellow)	//	red (pink, peach)
methyl red	orange (yellow)	//	red (pink)
bromophenol blue	blue (purple, violet)	//	yellow
bromocresol green	blue	//	yellow

[Colour change must be matched with named indicator.]

(*e*) CALCULATE: (i) **0.0432** M (6)
[Molarity divided by 4 to get 0.0108 - deduct 3 marks.]

$$\frac{\mathbf{25 \times \mathit{M}}}{\mathbf{1}} = \frac{\mathbf{21.6 \times 0.1}}{\mathbf{2}} \quad (3)$$

$$M = \mathbf{0.0432} \quad (3)$$

[M = 0.04 or 0.043, deduct 1 mark for inappropriate rounding off in (i) or for use of 0.04 or 0.043 in (ii) but deduction to made once only.]

(ii) **4.6** g l^{-1} (3)

0.0432 × 106 = **4.5792 / 4.58 / 4.6** (3)

(*f*) % WATER: **54 – 54.4%** (3)

Hydrated = 2.50 g/250 cm^3 / 10 g l^{-1}

Anhydrous = 1.14 – 1.15 g/250 cm^3 / 4.58 – 4.6 g l^{-1}

Water = 1.35 – 1.36 g/250 cm^3 / 5.4 – 5.44 g l^{-1}

$$\Rightarrow \frac{1.35/1.36}{2.5} \times 100 \ / \ \frac{5.4/5.44}{10} \times 100 = \mathbf{54}\% \quad (3)$$

VALUE OF *x*: **6.9 – 7** (6)

Formula mass of Na_2CO_3 = 106		**Formula mass of H_2O = 18**
Na_2CO_3 content = 4.6 g l^{-1} [4.5792 – 4.6] H_2O content = 10 – 4.6 = = 5.4 g l^{-1} [5.4 – 5.4208] $\frac{5.4}{4.6} = \frac{18x}{106}$ (3) x = **6.9 – 7** (3)	OR	Na_2CO_3 content = 1.15 g /250 cm^3 [1.14 - 1.15] H_2O content = 2.5 – 1.15 = 1.35 g /250 cm^3 [1.35 - 1.36] $\frac{1.35}{1.15} = \frac{18x}{106}$ (3) x = **6.9 – 7** (3)
Na_2CO_3 content = 4.6 g l^{-1} [4.5792 – 4.6] H_2O content = 10 – 4.6 = = 5.4 g l^{-1} [5.4 – 5.4208] $\frac{4.6}{106} : \frac{5.4}{18}$ / **0.043 : 0.3** (3) = 1 : **6.9 – 7** (3)	OR	Na_2CO_3 content = 1.15 g /250 cm^3 [1.14 -1.15] H_2O content = 2.5 – 1.15 = 1.35 g /250 cm^3 [1.35 - 1.36] $\frac{1.15}{106} : \frac{1.35}{18}$ / **0.0109 : 0.075** (3) = 1 : **6.9 – 7** (3)
Hydrated form: 10 g l^{-1} = 0.0432 M Formula mass = $\frac{10}{0.0432}$ / **231.5** (3) $x = \frac{231.5-106}{18}$ = **6.9 – 7** (3)	OR	Hydrated form: 2.5 g /250 cm^3 = 0.0108 mol Formula mass = $\frac{2.5}{0.0108}$ / **231.5** (3) $x = \frac{231.5-106}{18}$ = **6.9 – 7** (3)
$\frac{M_{r(hyd)}}{106} = \frac{10}{4.6^*}$ / $M_{r(hyd)}$ = **230.4**[230.4 -231.5] [*4.5792 – 4.6] (3) $x = \frac{230.4-106}{18}$ = **6.9 – 7** (3)	OR	$\frac{M_{r(hyd)}}{106} = \frac{2.5}{1.15^*}$ / $M_{r(hyd)}$ = **230.4** [230.4 - 232.5] [*1.14 – 1.15] (3) $x = \frac{230.4-106}{18}$ = **6.9 – 7** (3)
$\frac{mass_{water}}{106} = \frac{5.4}{4.6}$ [5.4 – 5.4208][4.5792 –4.6]/ $mass_{water}$ = **124.4** [124.4 – 125.5] (3) $x = \frac{124.4}{18}$ = **6.9 – 7** (3)	OR	$\frac{mass_{water}}{106} = \frac{1.35}{1.15}$ [1.35 - 1.36][1.14 - 1.15] / $mass_{water}$ = **124.4** [124.4 – 125.5] (3) $x = \frac{124.4}{18}$ = **6.9 – 7** (3)

[*Reminder: second 3 may be awarded consequentially.]*

QUSESTION 2

(*a*) PURPOSE: **to allow time for reaction / to bring reaction to completion / to maximise yield / to speed up** slow **reaction / to heat / to supply** activation **energy // without losing** volatile **material (ethanol, vapour, solvent) / without flask boiling dry** **(3 + 2)**

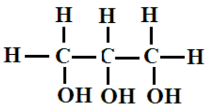
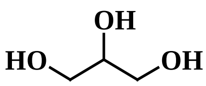
NAME: **base (alkaline)**-catalysed **hydrolysis / saponification** (3)
[Accept ‘substitution’.]

(*b*) SUBSTANCE: **ethanol** (3)

(*c*) EXPLAIN: to **precipitate (isolate, separate) the soap** / **soap insoluble in brine** (6)

(*d*) WHY: **to remove sodium hydroxide (NaOH) / sodium hydroxide could burn skin (eyes)** when soap used **/ sodium hydroxide is corrosive (harmful, dangerous) //**

HOW: **brine (salt solution) / ice-cold water** (2 × 3)

(*e*) DRAW or NAME:  /  / **$CH_2OHCHOHCH_2OH$** /

propane-1,2,3-triol / glycerol / glycerine (6)

[In the case of *single* **H** atoms bonded to a **C** atom in the expanded formula, the **H** symbol may be omitted.][Incorrect name cancels correct formula and *vice versa*.]

WHERE: in the **brine / filtrate** (3)
[Do not accept ‘in the flask’ unless correct flask specified, by drawing or description, e.g. flask in Stage 4, or named as Buchner.]

(*f*) GIVEN: **4.59** g (12)

$\frac{4.45}{890}$ (3) = **0.005** mol fat (3)

0.005 × 3 = **0.015** mol soap (3)

0.015 × 306 = **4.59** g (3)

For incorrect M_r (for 890 or 306), apply usual deductions of –3 and – 1, respectively. See page 1.

[For yield in g of 4.6, deduct 1 mark]

(*g*) EXPLAIN: **$C_{17}H_{35}$ {hydrocarbon part (end)} is non-polar (hydrophobic) and dissolves oils (non-polar** substances);
$–COO^{-}Na^{+}${ionic (hydrophilic) part (end)} attracted to (dissolves) salts in sweat (6)
[Charges required.]
[Use of terms including emulsions, colloids and micelles possible but answer must refer to *structure* *of soap to be acceptable.]*

QUESTION 3

(*a*) EXPLAIN: **change in concentration per unit time** of one reactant (product) / **rate of change of concentration** of one reactant (product) /

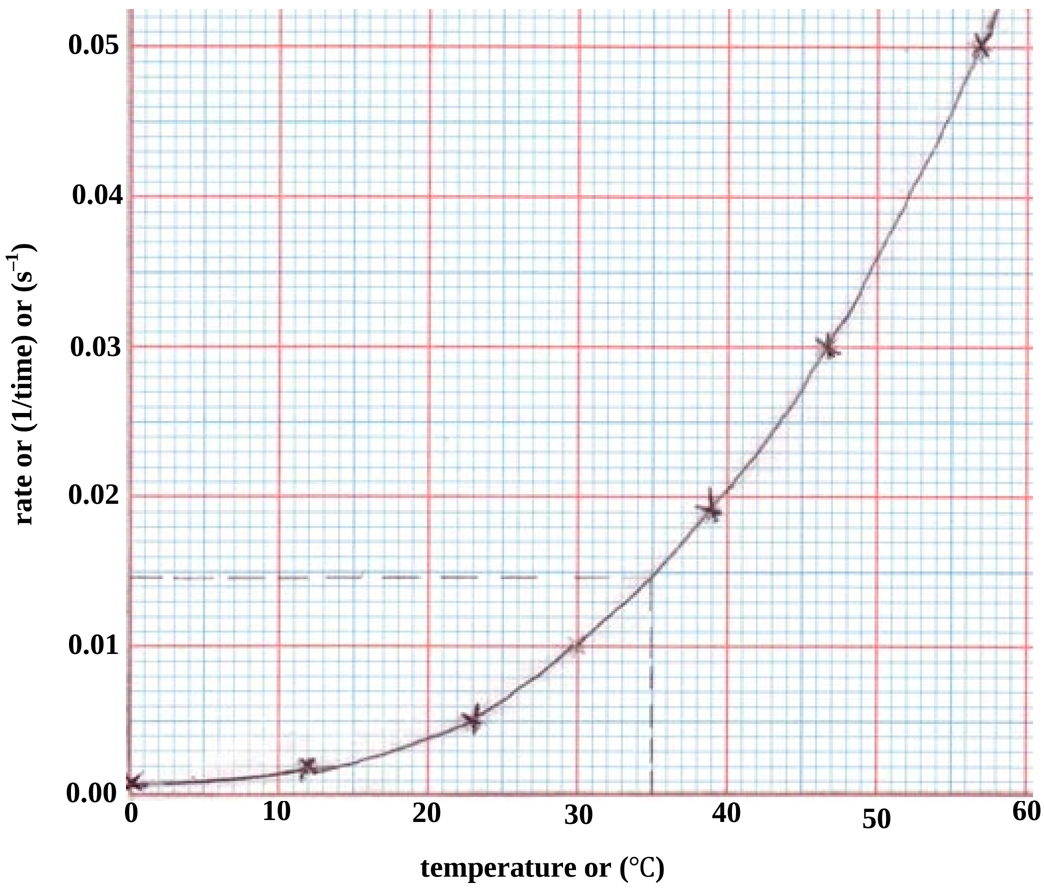
$$\frac{\textbf{change in concentration of one reactant (product)}}{\textbf{time}}$$ **(5)**

(*b*) (i) DESCRIBE: **cloudiness / precipitate** (3)

EXPLAIN: formation of **sulfur (S)** (3)

(ii) DESCRIBE: **stand flask on cross (mark, print, etc) / set up** smart phone **lux–meter** app // **note time (stop clock) when cross (mark, print, etc)** under flask **becomes invisible (obscured) /**
note time (stop clock) when mixture reaches certain opacity using smart-phone lux-meter app (2 × 3)

(*c*) PLOT: **both axes correctly labelled with quantity or unit //**
correct numeric scales on axes //
6 points correctly plotted //
correct curve [Straight line unacceptable.]
[Max 6 if graph paper not used.] (4 × 3)



(*d*) DESCRIBE: **rate increases** with temperature **//**
exponentially / and rate of **increase increases**

or

for every steady (regular) interval (e.g. **10 K, 10 °C) rise in temperature //**
rate multiplies by a constant factor (doubles, triples, etc) (2 × 3)

EXPLAIN: **more collisions reach activation energy** / **more effective (successful) collisions** (3)

[‘More molecules’ instead of ‘more collisions’ not acceptable.]

(*e*) USE: **66 – 72** s (6)

Rate from graph = 0.0145 s^{-1} [0.014 – 0.015]	(3)
Time = $\frac{1}{0.0145}$ = 69 s [66 – 72]	(3)

[Second 3 marks available if rate is outside range.][Where time not rounded off to whole number, deduct 1 mark.]

(*f*) WHAT: reaction times **double** original values **/** reaction **is twice as slow //**

JUSTIFY: **rate** directly **proportional to** thiosulfate **concentration /**
reaction **time inversely proportional to** thiosulfate **concentration /**
concentration thiosulfate **halved** (2 × 3)

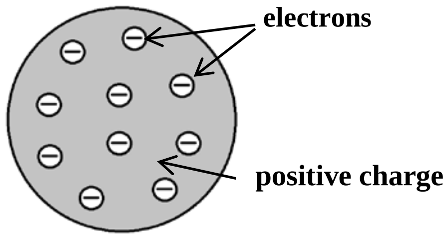
QUSESTION 4

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*) **green (yellow-green) //** (*ii*) **crimson (red)** (2 × 3)

(*b*) DESCRIBE: mass of **positive**ly-charged material **//**
with electrons (small **negative charges)**
scattered (embedded) in it

[Correctly labelled diagram acceptable.]



(2 × 3)

(*c*) WRITE: $^{223}_{87}\mathrm{Fr} \rightarrow \ \mathbf{^{223}_{88}Ra}$ / + $\mathbf{^{\ 0}_{-1}}\boldsymbol{e}$ (2 × 3)
[Allow if francium not written.] [Accept β instead of *e*.][Beta-particle as reactant not acceptable unless placed with a minus sign after Fr on the left.]

(*d*) STATE: **position (location) and momentum (velocity, speed, energy) //**
of an electron cannot be found (measured or known) simultaneously (at the same time) / of a particle cannot be found simultaneously (at the same time) with accuracy
(2 × 3)

(*e*) HOW: (*i*) **1** sigma **//** (*ii*) **2** pi (2 × 3)

(*f*) 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 × 10^{23}) //**
of **particles /**

or

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

(*g*) FIND: **SO_3** (6)

$\frac{40}{32} = 1.25;\quad \frac{60}{16} = 3.75$ / 1 : 3	(3)
=> SO_3	(3)

(*h*) CALCULATE: **0.196 – 0.199** mg (6)

$\frac{0.15}{127}$ / 0.00118 / 0.0012 //	$\frac{166}{127}$ = 1.31 //	$\frac{127}{166}$ × 100 = 76.51% //	(3)
× 166 = 0.196	× 0.15 = 0.196	0.15 ÷ 0.7651 = 0.196	(3)

[Unit 'mg' not required.][Accept **1.96 – 1.99 × 10^{-4} g** but deduct 1 mark if unit omitted.]

(*i*) STATE: **short chains // branches // rings (cyclic** compounds, **aromatic** compounds, compounds with a **benzene ring)**

ANY TWO: (2 × 3)

(*j*) STATE: **screening // passing over grit channels (traps) // settlement (sedimentation)**

ANY TWO: (2 × 3)

['Filtration' and 'flocculation' unacceptable but not contradictory.]

(*k*) **A** GIVE: **steel-making // breathing aid // diving //high altitude flying //climbing // rocket fuel // oxyacetylene flame (welding, cutting metals) // combat pollution // medical (hospital use, {CO poisoning , pulmonary disease, muscle injury} treatment, oxygen chamber, etc) // beauty (skin) treatment // recreation** in oxygen bar **// using bomb calorimeter (measuring heats of combustion)**

ANY TWO: (2 × 3)

B STATE: **corrosion resistance / protection // can be dyed // toughens metal**

ANY TWO: (2 × 3)

QUESTION 5

(*a*) NAME: **Bohr** **(5)**

DISTING: *energy level*: **discrete (fixed, restricted, definite, specific) energy of electron** in an atom /
energy of electron in orbit (shell, level) /
orbit (shell, level) which electrons of equal energy can **occupy** (3)

atomic orbital: **region (space, volume** *but not 'area' or 'place'***)** around the nucleus **//**

where there is a high probability of finding an electron / where an electron is most **likely to be found / where the probability (possibility) of finding an electron is 95% (or greater)** (2 × 3)

or

space occupied by electron //
described by approximate **solution of Schrödinger equation** (2 × 3)

WRITE: $\mathbf{1s^2\,2s^2\,2p_x^{\,2}\,2p_y^{\,2}\,2p_z^{\,2}\,3s^2\,3p_x^{\,1}\,3p_y^{\,1}}$ **/**

1*s*	2*s*	2*p*			3*s*	3*p*	
↓↑	↓↑	↓↑	↓↑	↓↑	↓↑	↓	↓

(6)

or

$\mathbf{1s^2\,2s^2\,2p^6\,3s^2\,3p^2}$ (3)

distribution of electrons in 2*p* and 3*p* clearly shown:

2*p*			3*p*	
↓↑	↓↑	↓↑	↓	↓

(3)

[Accept dots or crosses or other as indicator of electron distribution.]

HENCE: (*i*) **3 //**

(*ii*) **8** (2 × 3)

(*b*) DEFINE: the minimum **energy required to remove the most loosely-bound (outermost) electron // from an isolated (gaseous) atom in its ground state / from one mole of isolated (gaseous) atoms in their ground state** (2 × 3)

EXPLAIN: (*i*) **greater nuclear charge / greater number protons in nucleus // smaller atomic radius** (2 × 3)
['Greater atomic number' not acceptable.]

(*ii*) **greater atomic radius / most loosely-bound (outermost) electron farther from nucleus / most loosely-bound (outermost) electron more shielded from nucleus** (3)

['More shells' acceptable.]

(*c*) EXPLAIN: there are **three groups of ionisations (electrons, points) with gradual (small) energy differences** between them because they involve **electrons in the same** energy **level (shell) //**

there are **two bigger energy differences (jumps) between these groups of ionisations (electrons, points)** because the three **energy levels have significantly different** discrete (fixed, restricted, definite, specific) **energies**
(2 × 3)

or

sharp (bigger**) increase (jump)** in ionisation energy **for 5th (from 4th to 5th) electron** showing that this is the first electron to be **removed from 2nd (**n = **2, new, full, next, another)** main **level (shell) //**

sharp (bigger**) increase (jump)** in ionisation energy **for 13th (from 12th to 13th) electron** showing that this is the first electron to be **removed from 1st (**n = **1, new, full, next, another)** main **level (shell) //**

gradual (small) increase for first four electrons, therefore **in same** main **level (shell) /**
gradual (small) increase from 5th to 12th electrons, therefore **in same** main **level (shell) /**
gradual (small) increase from 13th to 14th electrons, therefore **in same** main **level (shell)**
ANY TWO: (2 × 3)

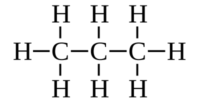
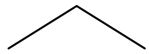
[Responses here must make sense and not just contain the correct phrases – beware of *incorrect* use of sublevel and orbital.]

OTHER: **line** emission (absorption) **spectra** of elements (3)

QUESTION 6

(*a*) NAME: **alkanes**

DRAW:

$CH_3CH_2CH_3$		

[*In fully-expanded structures the* **H***s may be omitted.*] **(5 + 3)**

(*b*) EXPL: propane smaller with **fewer electrons / smaller electron cloud / smaller M_r (smaller mass) / lighter molecule //**

therefore **weaker (fewer) intermolecular {forces between molecules (van der Waals, London, dispersion, dipole-dipole) forces }(attractions, interactions)** between molecules

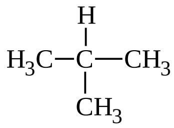
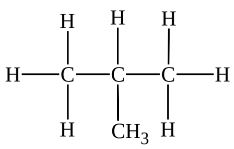
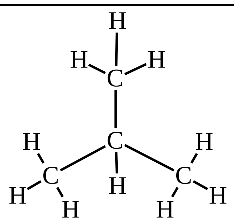
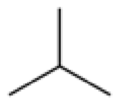
(2 × 3)

(*c*) (*i*) EXPL: compounds having the **same molecular formula / (same** set of **atoms) //**

but **different structural formulas (structures) / different arrangement of atoms**

(2 × 3)

(*ii*) DRAW:

$(CH_3)_2CHCH_3$	**$CH(CH_3)_3$**	
		

[In the case of *single* **H** atoms bonded to a **C** atom in the formula, the **H** symbol may be omitted.]
[Cancelling applies but do not apply cancellation to structure of butane if named.] (6)

(*d*) DEFINE: heat change when **1 mole** of substance //
is **burned (reacts) completely** in oxygen **/ is burned in excess oxygen**

(2 × 3)

WRITE: $\mathbf{C_4H_{10} \;+\; 6\tfrac{1}{2}O_2 \;\rightarrow\; 4CO_2 \;+\; 5H_2O}$

FORMULAS: (3) BALANCING: (3)

[Accept equation if given as part of CALCULATE below.] [Accept correct balanced equation with **$2C_4H_{10}$.**][Incorrect alkane is unacceptable.]

CALCULATE: **– 2877.3** kJ mol^{-1} (12)

$4C + 4O_2 \rightarrow 4CO_2$	ΔH =	**– 1574** kJ	(3)
$5H_2 + 2\frac{1}{2}O_2 \rightarrow 5H_2O$	ΔH =	**– 1429** kJ	(3)
$C_4H_{10} \rightarrow 4C + 5H_2$	ΔH =	**125.7** kJ	(3)
$C_4H_{10} + 6\frac{1}{2}O_2 \rightarrow 4CO_2 + 5H_2O$	ΔH =	**– 2877.3** kJ mol^{-1}	(3)

or

$$\Sigma\Delta H_c \quad \Sigma\Delta H_{f(products)} - \Sigma\Delta H_{f(reactants)}$$
$$= 4(-393.5) + 5(-285.8) - (-125.7)$$
$$= \mathbf{-1574}\ (3)\ \ \mathbf{-1429}\ (3) + \mathbf{125.7}\ (3)$$
$$= \mathbf{-2877.3}\ \text{kJ mol}^{-1} \quad (3)$$

[If $\mathbf{2C_4H_{10}}$ used above deduct 3 marks if 5754.6 kJ mol^{-1} is not divided by 2.]
[If incorrect alkane C_nH_{2n+2} used in calculation, allow 3 for nC correctly burned and 3 for $(n+1)H_2$ correctly burned and 3 for summation if correct.]

QUESTION 7

(*a*) DISTING: *strong acid*: **good proton (H^+) donor / readily donates proton (H^+) //**
weak acid: **poor (weak) proton donor** **(5 + 3)**
['Does not readily donate a proton' or references to dissociation not acceptable and cancellation applies.]

(*b*) IDENTIFY: **H_2O // NO_2^-** (2 × 3)

(*c*) DEFINE: **$-\log_{10}[H^+]$ / $-\log_{10}[H_3O^+]$** (3)
[Square brackets essential.][Mathematical definition expressed in words is acceptable.]

CALCULATE: **0.01** M (3)

$[H_3O^+]$ = inverse $\log_{10}(-2)$ = **0.01** M (3)

EXPLAIN: **concentration of hydronium (hydrogen) ions {$[H_3O^+]$, $[H^+]$} lower** than 0.2 M **/**

small (low, 5%) level of **dissociation (**only **slightly dissociated (ionised), almost undissociated, only 0.01 M dissociated) /**

a strong monobasic **acid with concentration 0.2 M would have a concentration of hydronium (hydrogen) ions {$[H_3O^+]$, $[H^+]$} = 0.2** /

a strong monobasic acid with concentration 0.2 M would have a pH = 0.7 /

***K_a* of nitrous acid** from data supplied is **only** $[0.01]^2 \div [0.2]$ = **5×10^{-4}** and is consistent with weak acid

(3)

WHAT: **0.01** M (3)

CALCULATE: $1 \times \mathbf{10^{-12}}$ M (6)

$[H_3O^+][OH^-]$ = 1×10^{-14}	(3)
$[OH^-]$ = $1 \times 10^{-14} \div 0.01$ = $1 \times \mathbf{10^{-12}}$ M	(3)
pH + pOH = 14 / pOH = 12	(3)
$[OH^-]$ = inverse $\log_{10}(-12)$ = $1 \times \mathbf{10^{-12}}$ M	(3)

(*d*) DESCRIBE: add freshly-prepared **iron(II) sulfate ($FeSO_4$)** solution **//**

trickle **H_2SO_4 (concentrated sulfuric acid)** dropwise
(carefully, slowly) down side of (into slanting) test-tube **//**

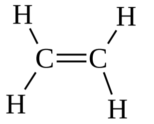
brown ring forms at junction of the two liquids (6 + 2 × 3)
[All marks available from a good labelled diagram.]

(*e*) EXPLAIN: causes **rapid growth of** water **plants (algae) /** causes **algal blooms //**
decay of these plants **by** aerobic **microorganisms (bacteria, decomposers) /**
respiration by decomposers (bacteria, microorganisms) of these plants uses up oxygen /
surface plants block light **preventing (reducing) photosynthesis** (2 × 3)

QUESTION 8

(*a*) GIVE: **ethene**

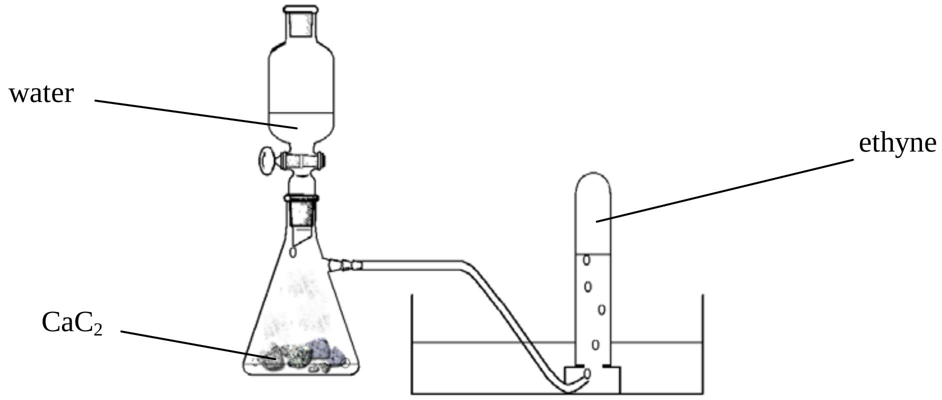
DRAW:

CH_2=CH_2	**H_2C=CH_2**	

[*In the fully-expanded structure the* **H***s may be omitted.*]

(3 + 2)

(*b*) DRAW:



water dropping on to / tap (dropping) funnel containing **water //**

calcium(II) di**carbide (CaC_2) //**

delivery tubing shown //

collection of ethyne (C_2H_2 or A) over water in test-tube, gas jar, etc
[Water in collection trough must be shown but need not be labelled.]
[Max 6 if no diagram.] [Ignore purification of ethyne if included.]

(4 × 3)

(*c*) DESCRIBE: **correct reagent {bromine (Br_2)** solution /
acidified potassium **manganate(VII) (permanganate) ($KMnO_4/H^+$) (MnO_4^-/H^+)**} **//**

initial colour of bromine {brown (red, orange, yellow) /
initial colour of acidified manganate(VII) {purple (pink)} //

colourless (decolorises, colour disappears) in case of B (**ethene, C_2H_4**) distinguishes B from C
[The reagent and colour change must correspond.][‘Clear’ unacceptable for ‘colourless’]

(3 × 3)

(*d*) (*i*) NAME: **free radical substitution** (3)

(*ii*) GIVE: *initiation*:

homolysis (splitting, fission) of chlorine molecule (Cl_2) into free **radicals (atoms, $Cl^\bullet$) by ultraviolet (uv) light** / $Cl_2 \xrightarrow{uv} 2Cl^\bullet$ / $Cl_2 \xrightarrow{uv} 2Cl$ (3)

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 (*d*).

propagation (*1*):

chlorine radical (atom, $Cl^\bullet$, Cl) reacts with ethane molecule (C_2H_6) giving hydrogen chloride (HCl) and an ethyl radical ($C_2H_5^\bullet$) /

$Cl^\bullet + C_2H_6 \rightarrow HCl + C_2H_5^\bullet$ / $Cl + C_2H_6 \rightarrow HCl + C_2H_5^\bullet$ (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 (*d*).]

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) /**

$C_2H_5^\bullet + Cl_2 \rightarrow C_2H_5Cl + Cl^\bullet$ / $C_2H_5^\bullet + Cl_2 \rightarrow C_2H_5Cl + Cl$ (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** (3)

[Accept 'chain reaction occurs' anywhere in (*d*).]

termination:

combination of remaining **radicals to form molecules (chlorine, chloroethane, butane) /**

$2Cl^\bullet \rightarrow Cl_2$ / $2Cl \rightarrow Cl_2$ /

$Cl^\bullet + C_2H_5^\bullet \rightarrow C_2H_5Cl$ / $Cl + C_2H_5^\bullet \rightarrow C_2H_5Cl$ /

$2C_2H_5^\bullet \rightarrow C_4H_{10}$ (3)

(*iii*) EXPLAIN: traces of **butane (C_4H_{10})** occur as consequence of **$C_2H_5^\bullet$ (ethyl radicals) combining** (6)

[**N.B.** The marks in part (iii) may only be given for answers in part (iii) and not for similar answers in part (ii). If the parts are not numbered, appropriate answers in part (ii) must be repeated if the marks available for part (iii) are to be awarded.]

QUESTION 9

(*a*) WRITE: $\dfrac{[\mathbf{N_2}][\mathbf{O_2}]}{[\mathbf{NO}]^2}$ **(5)**

(*b*) CALC: **0.9** mol (12)

$2NO \rightleftharpoons N_2 + O_2$ Start: **2** mole **0** mole **0** mole Equil: $\mathbf{2-2x}$ $\mathbf{x}$ $\mathbf{x}$ / $\mathbf{2-x}$ $\mathbf{\tfrac{1}{2}x}$ $\mathbf{\tfrac{1}{2}x}$ (3) $\dfrac{x^2}{(2-2x)^2} = \mathbf{20.25}$ (3) $\dfrac{x}{2-2x} = \mathbf{4.5}$ (3) $x = \mathbf{0.9}$ mole (3)	$2NO \rightleftharpoons N_2 + O_2$ Start: **2** mole **0** mole **0** mole Equil: $\mathbf{2-2x}$ $\mathbf{x}$ $\mathbf{x}$ / $\mathbf{2-x}$ $\mathbf{\tfrac{1}{2}x}$ $\mathbf{\tfrac{1}{2}x}$ (3) $\dfrac{x^2}{(2-2x)^2} = \mathbf{20.25}$ (3) $\mathbf{80x^2 - 162x + 81 = 0}$ (3) $(10x-9)(8x-9) = 0$ *or* $x = \dfrac{-(-162)\pm\sqrt{(-162)^2-4(80)(81)}}{2(80)}$ $x = \mathbf{0.9}$ mole

[Chemically impossible solution of correct quadratic equation retained, deduct 1 mark.]
[Quadratic equation with two chemically impossible solutions used, max mark is 7.]

(*c*) STATE: if system at **equilibrium** is subjected to a stress* (is disturbed) //

it tends (attempts, alters, moves, adjusts) to oppose (minimise, relieve) the stress* (disturbance, influence) (2 × 3)
[*The term "stress" may be replaced by "pressure, temperature, concentration" but only if all three are given. Do not accept "force" for "stress".]

WHAT: (*i*) value **decreases //**

(*ii*) **no effect** (2 × 3)
['No reaction' unacceptable.]

JUSTIFY: (*i*) **reaction shifts in endothermic (backward, left) direction to oppose added heat (temperature increase) / reaction shifts in endothermic (backward, left) direction to relieve stress** applied **//**

(*ii*) **only temperature** change **affects K_c / K_c constant at constant temperature** (2 × 3)
['What' and 'Justify' are linked.]

(*d*) NAME: **platinum // palladium // rhodium** ANY TWO: (2 × 3)
[Symbols unacceptable.]

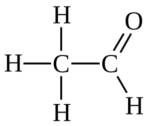
WHAT: **heterogeneous** / **surface adsorption** (3)
[‘Hetero-catalysis’ unacceptable.][Accept surface absorption.]

GIVE: **lower activation energy / reactants adsorbed** on surface **/ reactants** brought **closer on surface / higher concentration on surface / reactants occupy active sites** on surface **/ chemisorption (chemical attachment) / bond stretching (loosening, weakening) /reactants (reagents) oriented correctly** for reaction **/ activated catalyst formed** on catalyst surface **/ intermediate formed** on surface **between catalyst and reactant** (3)
[Reference alone to intermediate compound or complex not acceptable and cancellation applies.]

NAME: **lead** compounds **/ sulfur** compounds (3)
[Symbols unacceptable.]

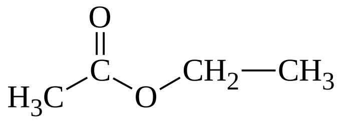
QUESTION 10

(*a*) (*i*) GIVE: production of **cellulose acetate /** production of **vinyl acetate (VAM) /** production of **polyvinyl acetate /** production of **acetic anhydride (acetylating agent) / solvent / vinegar / flavouring / preserving** **(4)**

(*ii*) DRAW:  (2×3)

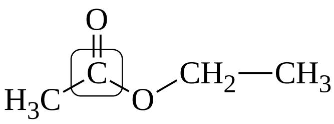
[Allow 3 for methyl even if not expanded. If fuly expanded the **H**s of the methyl group need not be shown.][Allow 3 for aldehyde group with all bonds shown.]

(*iii*) DRAW:

$CH_3COOC_2H_5$	

[In the fully-expanded form the **H**s need not be shown.]

(6)

IDENTIFY: **carbonyl carbon /**  [May be indicated by arrow, colouring, asterisk, etc.] (3)

[Accept correct planar carbon in an incorrect structure.]

(*iv*) HOW: **hydrogen (H_2) / hydrogenation //**
nickel (Ni) {platinum (Pt), palladium (Pd) or ruthenium (Ru)}

(2 × 3)

or

lithium aluminium hydride (lithium tetrahydroaluminate, $LiAlH_4$) /
sodium borohydride (sodium tetrahydroborate, $NaBH_4$) (6)

(*b*) DEFINE: (*i*) **number of nucleons (protons and neutrons)** in the atoms of an isotope (3)

(*ii*) **average mass of atom(s)** of element / **average mass of the isotopes** of an element **taking** their **abundances into account //**
relative to $\frac{1}{12}$ of mass of **carbon–12** atom (2 × 3)
[Relative to half (or any other incorrect fraction) of the mass of carbon–12 is a contradiction and cancellation applies.]

WHAT: **ionisation** to form positive ions **// separation** (2 × 3)
[Deflection not acceptable.]

LIST: **vaporisation, ionisation, acceleration, separation, detection** (3)
[Deflection not acceptable.]

CALCULATE: **69.798 (69.8)** **(7)**

69 × 60.1	=	4146.9	(2)
71 × 39.9	=	2832.9	(2)
100 atoms	=	6979.8	
A_r	=	69.798 (69.8)	(3)

[69.72 on its own from *Formulae and Tables* booklet is not acceptable.]
[Where candidate doesn't round off correctly - deduct 1 mark.]
[Where candidate includes unit deduct 1 mark.]

(*c*) DEFINE: (*i*) **loss** of electrons **//**

(*ii*) **increase** in oxidation number (2 × 3)

USE: (*iii*) oxidising agent: $\mathbf{NO_3^-}$ // **+5 (5)** → **+2 (2)** (2 × 3)
[N or nitrogen not acceptable.]

(*iv*) reducing agent: **Cd** // **0** → **+2 (2)** (2 × 3)

BALANCE: $\mathbf{3}Cd + \mathbf{8}H^+ + \mathbf{2}NO_3^- \rightarrow \mathbf{3}Cd^{2+} + \mathbf{2}NO + \mathbf{4}H_2O$ **(7)**
[Charges essential.]

[$3Cd + 2NO_3^- \rightarrow 3Cd^{2+} + 2NO$ ….allow 4 marks even if H^+ and H_2O not balanced.]
[Charges essential.]

QUESTION 11

(*a*) 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: **lone pair** of electrons **has greater repelling power than** a **bond pair** of electrons **//**
bonds (H atoms) in NH_3 pushed closer together than in SiH_4 **/**
ammonia has three bond pairs (one lone pair) where **silane has four bond pairs (no lone pair)** (2 × 3)

USE: electronegativity differences: **N – H = 0.84; Si – H = 0.3 => N – H** more polar **/**
electronegativity difference greater for N – H => N – H more polar (3)

WHICH: **ammonia //** (3)
JUSTIFY: in ammonia **hydrogen bonded to a small, highly (very) electronegative element (atom) /**
when hydrogen bonding occurs **hydrogen bonded to nitrogen, oxygen or fluorine** (3)
[Both parts to be linked].

GIVE: **centres of** positive and negative **charge coincide** / **dipole** moments **cancel / symmetrical (even) distribution (arrangement) of bonds in 3d(imensional space) around central atom** **(4)**
[Examples insufficient; reference to 'symmetry' **un**acceptable unless in sufficient detail; 'charges cancel' is **not** acceptable.]

(*b*) (*i*) HOW MANY: **0.05** mol (6)

M_r = **252** (3) $\quad \frac{12.6}{252}$ = **0.05** mol (3)

(*ii*) MASS: **7.6** g (6)

0.05 mol → **0.05** mol (3) 0.05 × 152 = **7.6** g (3)

(*iii*) VOLUME: **1.12** l / **1120** cm^3 / **1.12 × 10^{-3}** m^3 (6)

0.05 mol → **0.05** mol	(3)
0.05 × 22.4 = **1.12** l / 0.05 × 22,400 = **1,120** cm^3	(3)

(*iv*) NUMBER: **1.2 × 10^{23}** **(4)**

0.05 mol → **0.2** mol **(2)** 0.2 × 6 × 10^{23} = **1.2 × 10^{23}** **(2)**

HOW MANY: **3.6 × 10^{23}** (3)

3 × 1.2 × 10^{23} = **3.6 × 10^{23}** (3)

(*c*) **A** (*i*) WHY: due to dissolved **carbon dioxide (CO_2) / carbonic acid (H_2CO_3)** **(4)**

(*ii*) TWO: **damage to plants (trees) // fish kills // corrosion // leaching of minerals // damage to limestone (marble) buildings (monuments)**

ANY TWO: (2 × 3)

(*iii*) SHOW: $\mathbf{SO_2 + H_2O \rightarrow H_2SO_3}$ (3)

and

$\mathbf{SO_2 + \frac{1}{2}O_2 \rightarrow SO_3}$ **//**
$\mathbf{SO_3 + H_2O \rightarrow H_2SO_4}$ (2 × 3)

or

$\mathbf{SO_2 + \frac{1}{2}O_2 + H_2O \rightarrow H_2SO_4}$ **/** $\mathbf{H_2SO_3 + \frac{1}{2}O_2 \rightarrow H_2SO_4}$ (6)

[Equations need not be balanced.][Correct equivalent word equations acceptable.]

(*iv*) HOW: **burning** fossil fuels (coal, oil, etc) / waste **incineration** (3)

(*v*) AIR: **small population / island / little (no) heavy industry / windy /** prevailing SW **wind from (off)** Atlantic **/ burning smoky fuels in cities forbidden** (3)

B (*i*) EXPL: **regular solids //**

made up of particles (atoms, ions, molecules) / with faces intersecting at fixed (definite, specific, characteristic) angles / consisting of particles in a **lattice /** having its particles in a certain **packing arrangement** **(4 + 3)**

(*ii*) DESC: **layers** consisting **of hexagons** of C atoms **/ weak (intermolecular, van der Waals) forces between layers //**

layers can slide over each other / layers can rub off onto paper (2 × 3)

(*iii*) REFER: **all covalent bonds** between C atoms **//**
in a **tetrahedral** arrangement / has a **giant interlocking** structure (2 × 3)

(*iv*) EXPL: **outer (valence) electrons delocalised (form cloud) //**
electrons free to move (2 × 3)

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