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\(^-\)) / forms soluble (dissolves as) potassium triiodide (KI\(_3\)) / forms soluble (dissolves as) triiodide (I\(_3\)-) / \(\text{I}_2 + \text{I}^- \text{ (KI)} \rightleftharpoons \text{I}_3\text{ (KI\(_3\)} \) (6)

(b) DESCRIBE: pour some iodine (solution) into 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

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

STATE: blue-(black, navy) to colourless

(d) CALCULATE: (i) \(0.00125 \times (1.25 \times 10^{-3})\) moles

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

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

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

\[
\frac{0.025}{20} = \text{0.00125 moles} \quad (3)
\]

\[
[[\text{Addition must be shown for error to be treated as slip.}]\]

(ii) \(0.0025 \times (2.5 \times 10^{-3})\) moles

\[
0.00125 \times 2 = 0.00250 = \text{0.0025 moles} \quad (3)
\]

(iii) \(0.14 \text{ M}\)

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

\[
0.000140 \times 1000 = 0.140 = \text{0.140 M} \quad (3)
\]

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

\[
M = 0.140 = \text{0.140 M} \quad (3)
\]

(iv) \(35 \text{ g / L} [34.7 – 35 \text{ g / L}]\)

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

\[
[[\text{Addition must be shown for error to be treated as slip}]\]

[I 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] 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 = Na₂SO₃ / 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) //
white crystals (precipitate) form (appear, observed)  (2 × 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 ‘hot Buchner funnel’; ‘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)

\[
\begin{align*}
2.7 \times 1.04 & = 2.808 \text{ g} \quad (3) \\
\frac{2.808}{108^*} & = 0.026 \text{ moles} \quad (3) \\
0.026 \times 122^{**} & = 3.172 \text{ g} \quad (3)
\end{align*}
\]

\[
\frac{1.83}{3.172} \times 100 = 58\% \quad [57.69 - 58\%] \quad (3)
\]

\[
\begin{align*}
2.7 \times 1.04 & = 2.808 \text{ g} \quad (3) \\
\frac{2.808}{108^*} & = 0.026 \text{ moles} \quad (3) \\
\frac{0.015}{0.026} \times 100 & = 58\% \quad [57.69 - 58\%] \quad (3)
\end{align*}
\]

[*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

\[
\begin{align*}
1400 \text{ ppm} &= 1400 \text{ mg} / \text{L} = 1.4 \text{ g} / \text{L} & (3) \\
1.4 + 4 &= 0.35 \text{ g} / 250 \text{ cm}^3 & (3) \\
1400 \text{ ppm} &= 1400 \text{ mg} / \text{L} \Rightarrow 350 \text{ mg} / 250 \text{ cm}^3 & (3) \\
350 + 1000 &= 0.35 \text{ g} / 250 \text{ cm}^3 & (3)
\end{align*}
\]

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

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

SUGGEST: temporary hardness removed / only permanent hardness remaining / precipitate of carbonate (CO₃²⁻) formed by boiling and removed by filtration / soluble hydrogen carbonate (HCO₃⁻) removed as (converted to) solid precipitate, insoluble compound by boiling /

\[
\begin{align*}
\text{Ca(HCO}_3\text{)}_2 (aq) & \rightarrow / \Rightarrow \text{CaCO}_3 \downarrow + \text{H}_2\text{O} + \text{CO}_2 \\
\text{boiling} & / \text{boiling}
\end{align*}
\]

[Half equations above with Mg(HCO₃)₂ or HCO₃⁻ acceptable in place of Ca(HCO₃)₂.]

(d) IDENTIFY: DPD (diethylphenylenediamine) / KI (potassium iodide, I⁻) and H⁺ (acid)

DESCRIBE:

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

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

(e) WHICH: free chlorine

WHAT: (i) infection (disease) / microorganisms (pathogens, bacteria, germs, fungi, athlete's foot, ringworm present / more viruses (warts, verrucae) present ['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)

Higher Level Chemistry 2015 Page 4 of 16
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  

(b) EXPLAIN: 
average of mass numbers of the isotopes of an element / 
average mass of all (an) atom(s) of an element  
[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 / \( _0^1 n \rightarrow _1^1 p \) / 
and an electron (+ e) that is emitted  
[‘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 \((BF_3)\)] has three bond pairs of electrons // 
nitrogen [central atom of ammonia \((NH_3)\)] has three bond pairs and one lone pair of electrons

or

boron [central atom of boron trifluoride \((BF_3)\)] has three valence pairs of electrons // 
nitrogen [central atom of ammonia \((NH_3)\)] has four valence pairs of electrons

or

both ammonia and boron trifluoride have three bond pairs of electrons // 
but ammonia \((NH_3)\) also has one lone pair

[Marks available for good diagrams.]

(e) DEDUCE: 
\[ Cu_3N \]

\[
\frac{19.05}{63.5} = 0.300 = 0.3 \text{ moles; } \frac{1.4}{14} = 0.10 = 0.1 \text{ moles } / \Rightarrow 3 : 1 
\]

\[ \Rightarrow Cu_3N \]

(f) STATE: 
equal (same) volumes of gases contain equal (same) number of particles (molecules, moles) // at the same (constant) conditions of temperature and pressure  
[‘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  

[Unambiguous labelling acceptable instead of circle and rectangle.]
(h) IDENTIFY:

(i) sodium (Na) //
(ii) beryllium (Be)  

(ii) WHAT:
reduce (remove, lower) nitrates [nitrate identified by name (formula)] //
reduce (remove, lower) phosphates [phosphate identified by name (formula)]  

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

(j) CALCULATE: 0.005 \( (5 \times 10^{-3}) \) moles  

\[
\frac{1.85 \times 10^5 \times 6.50 \times 10^{-5}}{8.3 \times 293} = n \times \frac{1.85 \times 10^5 \times 6.50 \times 10^{-5}}{8.3 \times 293} / n = 0.005 \( 5 \times 10^{-3} \)
\]

or

\[
\frac{1.11 \times 10^{-4}}{224 \times 10^{-3}} = 0.005 \( 5 \times 10^{-3} \) \quad [*Using standard T & P and molar volume at s.t.p.*]  
\]

or

\[
P_1V_1 = P_2V_2^{**} \Rightarrow 1.85 \times 10^5 \times 6.50 \times 10^{-5} = 1.01 \times 10^5 \times V_2 \Rightarrow V_2 = 1.11 \times 10^{-4} \text{ m}^3 \quad (3)
\]

\[
\frac{1.19 \times 10^{-4}}{240 \times 10^{-3}} = 0.005 \( 5 \times 10^{-3} \) \quad [**Using room T & P and molar volume at room temperature.]  
\]

[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)  

[‘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: \( \text{fluorescence} / \text{glow} / \text{coloured light} / \text{shadow cast by anode (cross, object)} / \text{deflection of beam using magnetic (electric) field} / \text{paddle (wheel) rotated clockwise} / \text{paddle (wheel) pushed (moved to) right} / \text{using a charged electroscope} / \text{associated static electricity} \) (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 \( \text{passed straight through, were deflected slightly as they passed through} \) the gold foil // some alpha-particles deflected // some \( \text{(a few)} \) alpha-particles reflected \( \text{deflected straight back} \) along their original paths [Marks available from a good labelled diagram.] (3 × 3)

EXPLAIN: (i) repulsion \( \text{(deflection)} \) of positive alpha-particles (3)

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

(d) EXPLAIN: in the ground state the hydrogen electron occupies the lowest available energy level // the electron can jump \( \text{(move, become excited)} \) to a higher energy level \( \text{(state)} \) if it receives \( \text{(absorbs) a certain amount of energy (light, heat, electricity, a photon)} \) // excited \( \text{(higher energy)} \) state unstable \( \text{(temporary)} \) //

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

energy emitted \( \text{(given out) as photon (light of definite frequency, light of definite wavelength,} \ h f, h \nu \) thus giving rise to a spectrum //

energy emitted \( (h f, h \nu) \) corresponds to \( \text{=} \) difference between the two energy levels \( (E_2 - E_1) \) thus giving rise to a line on the spectrum \( / E_2 - E_1 = h f (h \nu) \) (3)

[Marks not awarded wherever \text{‘atom’ is incorrectly used instead of} \text{‘electron’}.]
[Some marks, maximum (6), available from a good labelled diagram.]

(e) SUGGEST: copper \( \text{[‘Barium’ or ‘boron’ acceptable.]} \) (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 \( \text{(distance to nucleus) of} 2s \text{ electron less than} 3s / \) nuclear attraction for \( 2s \) electron greater than \( 3s / \) \( 2s \text{ electron less shielded (screened) than} 3s \text{ from nucleus /} \) energy for ionisation \( \text{(removal of electron) of (from)} 2s \text{ greater than for} 3s / \) probability distribution \( \text{(volume, size) of} 2s \text{ less than} 3s \) (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) [‘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 / CH₃(CH₂)₆CH₃ // 2,2,4-trimethylpentane (isoctane) // (CH₃)₃CCH₂CH(CH₃)₂ (2 × 3) [Accept structures but not C₇H₁₆ or C₈H₁₈.]

(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 polyaromatics / eliminates need for lead compounds / emissions less toxic (2 × 3)

(e) CALCULATE: – 273.7 kJ mol⁻¹ (12)

\[
\begin{align*}
2C + O_2 & \rightarrow 2CO_2 \quad \Delta H = -787.0 \text{ kJ} \quad (3) \\
3H_2 + 1\frac{1}{2}O_2 & \rightarrow 3H_2O \quad \Delta H = -857.4 \text{ kJ} \quad (3) \\
2CO_2 + 3H_2O & \rightarrow C_2H_5OH + 3O_2 \quad \Delta H = 1370.7 \text{ kJ} \quad (3) \\
2C + 3H_2 + \frac{1}{2}O_2 & \rightarrow C_2H_5OH \quad \Delta H = -273.7 \text{ kJ mol}^{-1} \quad (3)
\end{align*}
\]

\[\Sigma \Delta H_c = \Sigma \Delta H_{f(products)} - \Sigma \Delta H_{f(reactants)}\]

\[\Delta H_{f(ethanol)} = 1370.7 \text{ (3)} - 787.0 \text{ (3)} - 857.4 \text{ (3)} = -273.7 \text{ kJ mol}^{-1} \quad (3)\]

[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, greener, 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, CH₄, hydrocarbons) // dehydrocyclisation (reforming) // electrolysis of water (H₂O) / 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

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

**IDENTIFY:** methanal (formaldehyde, HCHO) // water (H₂O) // hydrogen (H₂) ANY TWO: (2 × 3) ['Methanoic acid’ unacceptable but does not cancel.]

(d) **WHAT:** adsorption / chemisorption ['Adsorption’ or ‘adsorption’ or ‘adsorbance’ are allowable.]

**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

**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 ['Adsorbed’ 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) suitable curve with energy of reactants greater than energy of products ΔH (between reactant and product energies) Eₐ (between reactant energy and peak) ['Reaction’ with an arrow is acceptable to label x-axis.]

Higher Level  Chemistry 2015  Page 9 of 16
QUESTION 8

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

(3 + 3 + 2)

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

(3)

(c) IDENTIFY: 
broken: C to O pi (\(\pi\)) bond / (pi (\(\pi\)) 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.]

(3 × 3)

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

(2 × 3)

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\(_4\)) 

['Reduction' or 'hydrogenation' acceptable for (3).] 

(6)

(e) IDENTIFY 
A (C\(_3\)H\(_6\), propene) = – 48 °C (lowest boiling point) // 
B (CH\(_3\)CHOHCH\(_3\), propan-2-ol, 2-propanol) = 82 °C (highest boiling point) // 
C (CH\(_3\)COCH\(_3\), propanone) = 56 °C (middle boiling point) ANY TWO: (2 × 3)

JUSTIFY: 
A (C\(_3\)H\(_6\), propene) has van der Waals (London, dispersion, weakest dipole-dipole, temporary, transient) forces (attractions, bonds) between the molecules // 
B (CH\(_3\)CHOHCH\(_3\), propan-2-ol, 2-propanol) has hydrogen (strongest dipole-dipole) bonds (forces, attractions) between the molecules // 
C (CH\(_3\)COCH\(_3\), 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 $\text{H}^+$ (hydrogen ion) by dissociation in water (aqueous solution) //
(ii) Bronsted-Lowry acid: proton (hydrogen ion, $\text{H}^+$) donor

(b) DEFINE: $-\log_{10}[\text{H}^+] / -\log_{10}[\text{H}_3\text{O}^+] /$ negative log to base ten of hydrogen (hydronium) ion concentration in moles per litre

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

[c] "Temperature dependent / (25 °C) acceptable."]

[c] Valid range 1 – 14 unacceptable but does not cancel.

(c) GRAPH: See graph on next page. 
both axes correctly labelled (pH, V, volume, cm$^3$, NaOH) / appropriate, correct numeric scales on both axes / smooth curve of correct shape corresponding to 0 -15 cm$^3$ NaOH added and from 25- 40 cm$^3$ NaOH added / careful plotting of vertical part

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

(d) (i) CALCULATE: $0.014 \text{ M} [0.0139 – 0.014 \text{ M}]

\[
\begin{align*}
[H^+] &= \sqrt{k_a[\text{CH}_3\text{COOH}]} / \text{inverse log} (-3.3) / 5.01 \times 10^{-4} \\
-\log_k[\text{CH}_3\text{COOH}] &= 3.3 / \log_k[k_a[\text{CH}_3\text{COOH}]] = -3.3 \\
k_a &= \frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{COOH}]} = \frac{[\text{H}^+]^2}{[\text{CH}_3\text{COOH}]} / 1.8 \times 10^{-5} = \frac{[5.01 \times 10^{-4}]^2}{[\text{CH}_3\text{COOH}]} \\
[\text{CH}_3\text{COOH}] &= 0.014 \text{ M} [0.0139 – 0.014 \text{ M}] \\
\text{Take} [\text{acid}] \text{ or } [\text{HA}] \text{ or } \text{to be } [\text{CH}_3\text{COOH}] \text{ and } [\text{A}^-] \text{ to be } [\text{CH}_3\text{COO}^-]
\]

or

\[
\begin{align*}
[H^+] &= \sqrt{k_a[\text{CH}_3\text{COOH}]} / \text{inverse log} (-3.3) / 5.01 \times 10^{-4} \\
-\log_k[\text{CH}_3\text{COOH}] &= 3.3 / \log_k[k_a[\text{CH}_3\text{COOH}]] = -3.3 \\
k_a &= \frac{[\text{CH}_3\text{COOH}]}{1.8 \times 10^{-5} \times [\text{CH}_3\text{COOH}]} = (5.01 \times 10^{-4})^2 \\
[\text{CH}_3\text{COOH}] &= \frac{(5.01 \times 10^{-4})^2}{1.8 \times 10^{-5}} = 2.51 \times 10^{-7} / \text{to be } 0.014 [0.0139 – 0.014 \text{ M}] \\
\text{Take} [\text{acid}] \text{ or } [\text{HA}] \text{ or } \text{to be } [\text{CH}_3\text{COOH}] \text{ and } [\text{A}^-] \text{ to be } [\text{CH}_3\text{COO}^-]
\]

[1 mark deducted for incorrect rounding off.]

(ii) MAKE USE: $20 \text{ cm}^3$

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

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)

[K$_a$ (K$_{\text{In}}$, $pK_a$, $pK_{\text{In}}$) value of phenolphthalein acceptable for (4).]

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

(a) DISTING: 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 (Br₂) solution (water) / acidified potassium manganate(VII) (permanganate) / (KMnO₄/H⁺) / (MnO₄⁻/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 Br₂ solution easily / does not decolourise acidified KMnO₄ 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 Cu²⁺, changed to Cu²⁺) / impure copper acts as (is attached to) anode (positive electrode) // pure copper acts as (is attached to) cathode (negative electrode) // copper ions (Cu²⁺) 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: Cu²⁺ + 2e⁻ → Cu //

Cu → Cu²⁺ + 2e⁻ / Cu – 2e⁻ → Cu²⁺ (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’.]
(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 \times 10^{23});** //
of particles */
or
amount equal to the relative formula (molecular) mass (M_r) //
expressed **in grams**

(ii) HOW: 0.4 mol

\[
\frac{7.6}{76^*} = 0.10 = 0.10 \text{ mol Mg}_2\text{Si} \quad (3)
\]

\[
0.10 \text{ mol Mg}_2\text{Si} \rightarrow 0.40 = 0.4 \text{ mol Mg} \quad (3)
\]

or

\[
\frac{4 \times 24 \times 7.6}{76^*} = 9.6 \text{ g Mg} \quad (3)
\]

\[
9.6 \div 24 = 0.4 \text{ mol Mg} \quad (3)
\]

(iii) CALC: 0.4 mol

\[
0.10 \text{ mol Mg}_2\text{Si} \rightarrow 0.40 = 0.4 \text{ mol HCl} \quad (3)
\]

or

\[
\frac{4 \times 36.5}{76^*} \times 7.6 = 14.6 \div 36.5 = 0.4 \text{ mol HCl} \quad (3)
\]

WHAT: 19 g MgCl_2

\[
0.10 \text{ mol Mg}_2\text{Si} \rightarrow 2 \times 0.10 = 0.2 \text{ mol MgCl}_2 \quad (3)
\]

\[
95^{**} \times 0.20 = 19 \text{ g MgCl}_2 \quad (3)
\]

or

\[
76^*\text{ g Mg}_2\text{Si} \rightarrow 2 \times 95^{**} / 190 \text{ g MgCl}_2 \quad (3)
\]

\[
7.6 \text{ g Mg}_2\text{Si} \rightarrow 190 \div 10 = 19 \text{ g MgCl}_2 \quad (3)
\]

(iv) WHAT: 4.8 litres (4,800 cm^3)

\[
0.10 \text{ mol Mg}_2\text{Si} \rightarrow 0.10 \text{ mol SiH}_4 \rightarrow 2 \times 0.10 = 0.2 \text{ mol O}_2 \quad (2)
\]

\[
0.20 \times 24 = 4.8 \text{ litres} \quad (2)
\]

or

\[
76^*\text{ g Mg}_2\text{Si} \rightarrow 2 \times 24 / 48 \text{ L O}_2 \quad (2)
\]

\[
7.6 \text{ g Mg}_2\text{Si} \rightarrow \frac{48}{76^*} \times 7.6 = 4.8 \text{ L O}_2 \quad (2)
\]

[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)

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

(c) **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

<table>
<thead>
<tr>
<th>( A ) ⇌ ( B ) + ( C )</th>
<th>( A ) ⇌ ( B ) + ( C )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start: ( 3.0 \text{ mol} / \text{L} )</td>
<td>Start: ( 30 \text{ mol} )</td>
</tr>
<tr>
<td>Equil: ( (3 – x) )</td>
<td>Equil: ( (30 – x) )</td>
</tr>
<tr>
<td>( K_c = \frac{(x)^2}{(3.0 – x)} = 4 )</td>
<td>( K_c = \frac{(x)^2}{(30 – x)} = 4 )</td>
</tr>
<tr>
<td>( x^2 + 4x – 12.0 = 0 )</td>
<td>( x^2 + 40x – 1200 = 0 )</td>
</tr>
<tr>
<td>( (x + 6)(x – 2) = 0 / x = \frac{-(4)±\sqrt{(4)^2–4(1)(-12.0)}}{2} )</td>
<td>( (x + 60)(x – 20) = 0 / x = \frac{-(40)±\sqrt{(40)^2–4(1)(-1200)}}{2} )</td>
</tr>
<tr>
<td>( x = 2.0 \text{ mol} / \text{L} )</td>
<td>( x = 20 \text{ mol} )</td>
</tr>
<tr>
<td>( \Rightarrow 5.0 \text{ mol} / \text{L total} )</td>
<td>( \Rightarrow 50 \text{ mol total} )</td>
</tr>
</tbody>
</table>

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

**DEDUCE:** endothermic (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\(^{•}\)) [Unbalanced equation acceptable.] (3)

(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: \(\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2\) /
\(\text{Fe}_2\text{O}_3 + 3\text{C} \rightarrow 2\text{Fe} + 3\text{CO}\) /
\(2\text{Fe}_2\text{O}_3 + 3\text{C} \rightarrow 4\text{Fe} + 3\text{CO}_2\) FORMULAE: (3) BALANCING: (3)

(iii) USE: \(\text{CaO} + \text{SiO}_2 \rightarrow \text{CaSiO}_3\) /
\(\text{CaO} + \text{Al}_2\text{O}_3 \rightarrow \text{CaAl}_2\text{O}_4\{\text{Ca(AlO}_2\text{)}_2\}\) 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.]