SimpleStudy

PRACTICE MARKING SCHEME

LEAVING CERTIFICATE · HIGHER LEVEL · SAMPLE PAPER 2 · 2027

Chemistry

Total marks	Duration	Structure
300	2 hr 30 min	7 questions

About this document

A practice marking scheme produced by SimpleStudy to help students and teachers prepare for the Leaving Certificate examination in Chemistry. The State Examinations Commission has published this sample paper without a marking scheme; the mark allocations and answers set out here are indicative.

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Marking Scheme

This marking scheme accompanies the State Examinations Commission's Sample Paper 2 in Leaving Certificate Chemistry, Higher Level. It is intended to support candidates and teachers preparing for the examination. It is not an official State Examinations Commission document.

General Marking Guidelines

- Accept all reasonable responses; the lists in this scheme are indicative, not exhaustive.
- Credit content that is correct even where it is poorly expressed.
- No penalty for spelling or grammar unless the meaning is unclear.
- Where a candidate contradicts themselves, award the lower mark.
- Credit accurate labelling on diagrams, and credit a correct answer given as a labelled diagram where the question does not require prose.
- Where a candidate offers more points than the number asked for, mark the first *n* presented, unless a later point is clearly labelled as a replacement.

Six additions for this paper:

- There are seven questions, each worth 50 marks. Candidates answer Question 1 and any five others, so six questions make up the 300 marks. Where a candidate answers all seven, mark all seven and credit the best six.
- **Formulae and Tables.** Candidates have the booklet and are directed to use its data, including atomic numbers and relative atomic masses. Where a part sends them to a particular page — 1(a)(i) to page 81, 1(d) to page 83 — the answer must rest on that data, and an answer that reaches the right conclusion without quoting it earns the reasoning marks but not the data marks.
- **Units and significant figures.** The paper warns that marks may be lost where units are omitted. In this scheme a calculated answer carries one mark for the correct unit unless the part states otherwise. Answers given to three or more significant figures are acceptable throughout; where a part states an acceptable range, that range governs.
- **Error carried forward.** Where a candidate uses an incorrect value from an earlier part correctly in a later one, award the later marks in full. An error is penalised once only. This matters particularly in Question 4, where parts (vii) to (x) form a single chain.
- **Chemical equations.** An equation earns its marks first for correct reactants and products and then for balancing; award the formulae marks where the species are right but the coefficients are wrong. State symbols are required only where the part asks for them or the printed equation uses them.
- **Units of volume and concentration.** This scheme follows the paper, which expresses concentrations in M and volumes in cm^3, and writes "litres" in words where a part calls for it. Accept any correct equivalent a candidate uses, including mol dm^{-3} and dm^3.

Examiner note on the paper as printed. *Three small points, none of which affects what a candidate should write. Part 7(vi) prints "the density of the of hydrochloric acid"; mark it as the density of the hydrochloric acid. Part 2(c)(ii) gives K_c = 0.5 without a unit; for this equation the unit is litres per mole, and it is not required from candidates. Part 6(b)(ii) directs a reduction sequence that does not occur under the conditions its own stem specifies — see the note at that part.*

Paper Structure

Question 1	**50 marks**	Compulsory. Bonding and the octet rule, bond enthalpies, the carbon cycle, isotopes and relative atomic mass, and free radical substitution.

Question 2	**50 marks**	Emissions data, oxidation numbers, calcium ammonium nitrate, a test for nitrate, and a quantitative equilibrium.
Question 3	**50 marks**	The laboratory preparation of ethene and its safety, poly(ethene), and the alkene isomers of C_4H_8.
Question 4	**50 marks**	A vinegar titration monitored by pH meter, the full concentration calculation, standardisation, and the acidity of ethanoic acid.
Question 5	**50 marks**	Classifying alcohols, oxidation and reduction of alcohols, surface adsorption catalysis, esters and a gas law calculation.
Question 6	**50 marks**	The lithium-ion cell as a galvanic cell, and the synthesis of benzoic acid with a percentage yield.
Question 7	**50 marks**	Rate of reaction by loss of mass, graphing, limiting reactant, reaction profile, and tests for lithium and carbonate ions.
Total	**300 marks**	Question 1 and any five of Questions 2 to 7.

Only the question numbers are printed on the paper; the descriptions above are supplied by this scheme for navigation only.

Grading Descriptors (all parts carrying a development element)

High (H) Point accurately named and developed with correct chemical reasoning, applied to the substance, data or context the part supplies. Full marks for the point.

Mid (M) Relevant point named with partial development, or chemically correct but not applied to the data or context the part supplies. Award the naming marks in full plus roughly half the development marks, rounded up to a whole mark.

Low (L) Point named or asserted only; vague, or development that does not follow from the point named. Naming marks only.

No criterion grid is used on this paper. *The extended parts — for example 1(c), 4(i), 4(xii), 5(c)(iii) and 7(x) — are marked by required elements rather than holistically. All internal splits are indicative: the paper prints a total of 50 marks for each question and no sub-part marks anywhere. The splits reconcile upward to each question total and to the paper total of 300 marks.*

Question 1 — 50 marks

Compulsory. Candidates answer all parts.

Indicative mark allocation: (a)(i) 4 · (a)(ii) 3 · (a)(iii) 4 · (b)(i) 3 · (b)(ii) 8 · (c) 7 · (d)(i) 2 · (d)(ii) 5 · (d)(iii) 3 · (e)(i) 4 · (e)(ii) 5 · (e)(iii) 2 = 50 marks.

(a) Bonding in beryllium fluoride (11 marks)

Part	Acceptable Answer(s)	Marks
(i) Nature of the bonding	From page 81 of the booklet, beryllium has an electronegativity of 1.57 and fluorine 3.98 (2); the difference is 2.41, well above 1.7, so the bonding is predicted to be **ionic** (2).	**4**
(ii) Formula	**BeF_2**	**3**
(iii) The octet rule	Beryllium has only two electrons in its outer energy level and loses both in forming the Be^{2+} ion (2). That leaves it with the electron arrangement of helium — a filled first level holding two electrons, not an octet of eight (2). **Also accept** the covalent reading: in a covalent BeF_2 molecule beryllium forms only two bonds and so has just four electrons around it. Credit it provided it is consistent with the candidate's own answer to part (i).	**4**

Examiner note: *the electronegativity rule gives "ionic", and that is the expected answer to (i). In practice beryllium fluoride has substantial covalent character, because the small, highly charged Be^{2+} ion polarises the fluoride ions strongly. A candidate who calculates the difference of 2.41 correctly and then qualifies the prediction on those grounds should not lose marks for the qualification.*

(b) Bond enthalpy (11 marks)

Part	Acceptable Answer(s)	Marks
(i) Bond enthalpy	The energy required to break one mole of a particular covalent bond, with the substance in the gaseous state. The values quoted are averages taken across many different compounds containing that bond.	**3**
(ii) ΔH for the combustion	*3 marks for bonds broken, 3 for bonds formed, 1 for the subtraction, 1 for the sign and unit.* Bonds broken: 4(C–H) + 2(O=O) = 4(413) + 2(498) = 1652 + 996 = 2648 kJ Bonds formed: 4(O–H) + 2(C=O) = 4(464) + 2(805) = 1856 + 1610 = 3466 kJ ΔH = 2648 − 3466 = **−818 kJ mol^{-1}** The negative sign must be present; an answer of +818 earns a maximum of 6.	**8**

(c) The carbon cycle and the greenhouse effect (7 marks)

Marked by required elements. Words, diagrams or a combination are equally acceptable.

Part	Acceptable Answer(s)	Marks
Expected elements	• Carbon moves continuously between the atmosphere, the oceans, living organisms and rocks (1). • Photosynthesis removes CO_2 from the atmosphere; respiration, decay and natural fires return it (2). • The natural cycle keeps atmospheric CO_2 roughly in balance, and the CO_2 present absorbs outgoing infrared radiation, keeping the Earth at about 15 °C rather than about −18 °C — the natural greenhouse effect, without which the planet would be uninhabitable (2). • Human activity adds carbon the cycle cannot remove at the same rate: burning fossil fuels releases carbon locked away for millions of years, and deforestation reduces the photosynthetic sink (1). • The extra CO_2 enhances the greenhouse effect and raises global temperatures — the human-influenced or enhanced greenhouse effect (1).	**7**

(d) Isotopes of boron (10 marks)

Part	Acceptable Answer(s)	Marks
(i) Neutrons in ^{10}B	10 − 5 = **5**	**2**
(ii) Relative atomic mass	(10.012937 × 19.9 + 11.009305 × 80.1) ÷ 100 = (199.26 + 881.85) ÷ 100 = **10.81** *3 marks for the method, 2 for the answer.* Accept 10.8.	**5**
(iii) Why not a whole number	When protons and neutrons bind together in a nucleus a small amount of mass is converted into the binding energy that holds the nucleus together, so the mass of the atom is slightly less than the sum of the masses of its particles (2). The atomic mass unit is itself defined as one twelfth of the mass of a carbon-12 atom, so only carbon-12 has a whole-number mass by definition (1).	**3**

(e) Free radical substitution (11 marks)

Part	Acceptable Answer(s)	Marks
(i) Initiation	Ultraviolet light or heat supplies the energy that breaks the Cl–Cl bond homolytically, one electron going to each atom, producing two chlorine free radicals: **$Cl_2 \rightarrow 2Cl\cdot$** *2 marks for the equation, 2 for homolytic fission brought about by UV light.*	**4**
(ii) Propagation	Both steps are required: **$Cl\cdot + C_2H_6 \rightarrow C_2H_5\cdot + HCl$** (2) **$C_2H_5\cdot + Cl_2 \rightarrow C_2H_5Cl + Cl\cdot$** (2) Each step consumes one radical and generates another, so the chain continues (1).	**5**

Part	Acceptable Answer(s)	Marks
(iii) Hydrocarbon product	**Butane** (C_4H_{10}), from $C_2H_5\cdot + C_2H_5\cdot \rightarrow C_4H_{10}$. Do not accept chloroethane or chlorine, neither of which is a hydrocarbon.	**2**

Question 2 — 50 marks

Candidates answer any five of Questions 2 to 7. Each carries 50 marks.

Indicative mark allocation: (a)(i) 3 · (a)(ii) 4 · (a)(iii) 4 · (a)(iv) 4 · (b)(i) 4 · (b)(ii) 8 · (b)(iii) 5 · (b)(iv) 6 · (c)(i) 5 · (c)(ii) 7 = 50 marks.

(a) Nitrous oxide emissions and oxidation numbers (15 marks)

Part	Acceptable Answer(s)	Marks
(i) Year of closure	**2002.** Accept 2003 where the candidate explains that it is the first year showing no industrial emissions.	**3**
(ii) Why the EPA is reliable	It is the independent state agency with statutory responsibility for monitoring and reporting emissions (2); it uses standardised, internationally agreed methods, its inventories are verified and reported to the EU and the United Nations, and it has no commercial interest in the results (2).	**4**
(iii) Oxidation number in N_2O	$2N + (-2) = 0$, so N = **+1**	**4**
(iv) Oxidation number in HNO_3	$(+1) + N + 3(-2) = 0$, so N = **+5**	**4**

Examiner information only. *On the printed graph the Industrial Processes contribution is at full height from 1990 to 2001, falls to about a third of that height in 2002, and is absent from 2003 onwards. A part-year of emissions in 2002 followed by none is consistent with closure during 2002, so either year is defensible where the reasoning is given; 2002 alone needs no justification.*

(b) Calcium ammonium nitrate (23 marks)

Part	Acceptable Answer(s)	Marks
(i) Ca^{2+} configuration	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$	**4**
(ii) Percentage of nitrogen	$5Ca(NO_3)_2$ = 820.5; NH_4NO_3 = 80.0; $10H_2O$ = 180.0; total **M = 1080.5** (4) Nitrogen present: 10 + 2 = 12 atoms × 14.0 = 168.0 (2) % N = 168.0 ÷ 1080.5 × 100 = **15.5%** (2)	**8**
(iii) Acid or base	The ammonium ion acts as an **acid** (2). It donates a proton to the water molecule, $NH_4^+ + H_2O \rightharpoonup NH_3 + H_3O^+$, and a proton donor is an acid on the Brønsted-Lowry definition (3).	**5**

Part	Acceptable Answer(s)	Marks
(iv) Test for nitrate ions	*3 marks for the reagents, 3 for the observation.* The brown ring test: dissolve the sample and add freshly prepared iron(II) sulfate solution, then pour concentrated sulfuric acid slowly down the inside of the tilted test tube so that it forms a layer beneath. A **brown ring** forms at the junction of the two liquids where nitrate is present. **Also accept:** warming the sample with sodium hydroxide solution and Devarda's alloy, which reduces nitrate to ammonia, detected by its smell and by damp red litmus paper turning blue at the mouth of the tube.	**6**

(c) The NO_2 / N_2O_4 equilibrium (12 marks)

Part	Acceptable Answer(s)	Marks
(i) Exothermic or endothermic	The forward reaction is **exothermic** (2). The mixture is almost colourless at the lowest temperatures and deepens to brown as the temperature rises, so heating shifts the equilibrium towards brown NO_2, the reverse direction. By Le Châtelier's principle, raising the temperature favours the endothermic direction; the reverse reaction is therefore endothermic and the forward reaction exothermic (3).	**5**
(ii) Moles at equilibrium	$K_c = [N_2O_4] \div [NO_2]^2$. Initially $[NO_2] = 2$ and $[N_2O_4] = 1$ in a 1 litre vessel, so the quotient is $1 \div 4 = 0.25$, which is less than K_c, and the reaction proceeds forward (1). Let $2x$ mol of NO_2 react, forming x mol of N_2O_4 (1): $(1 + x) \div (2 - 2x)^2 = 0.5$ $1 + x = 2 - 4x + 2x^2$, giving $2x^2 - 5x + 1 = 0$ (2) $x = (5 - \sqrt{17}) \div 4 = 0.219$ (2) **$NO_2 = 2 - 2(0.219) = 1.56$ mol; $N_2O_4 = 1 + 0.219 = 1.22$ mol** (1)	**7**

Check: $1.22 \div 1.56^2 = 0.50$. The second root, $x = 2.28$, is rejected because it would require more NO_2 to react than is present.

Question 3 — 50 marks

Candidates answer any five of Questions 2 to 7. Each carries 50 marks.

Indicative mark allocation: (a)(i) 5 · (a)(ii) 3 · (a)(iii) 4 · (a)(iv) 4 · (a)(v) 4 · (a)(vi) 3 · (a)(vii) 4 · (b)(i) 2 · (b)(ii) 4 · (b)(iii) 5 · (c) 12 = 50 marks.

(a) Preparation of ethene (27 marks)

Part	Acceptable Answer(s)	Marks
(i) Labelling the compounds	*2 marks per compound correctly named and located, to a maximum of 5.* Ethanol absorbed in the mineral wool or glass wool at the closed end of the tube; aluminium oxide as the catalyst in the middle of the tube, where the heat is applied. Accept pumice or broken porous pot as the catalyst. The water in the trough may be labelled for the fifth mark.	**5**
(ii) Missing apparatus	A **Bunsen burner**, or other heat source, drawn beneath the tube and positioned under the catalyst rather than under the mineral wool. *2 marks for the burner, 1 for the correct position.*	**3**
(iii) Suck-back	When the heating stops, the gas remaining in the apparatus cools and contracts, lowering the pressure inside (2); water from the trough is then pushed up the delivery tube by atmospheric pressure and can reach the hot glass, which may crack it (2).	**4**
(iv) Preventing suck-back	Lift the delivery tube clear of the water in the trough before removing the Bunsen burner, so that air rather than water is drawn back (3). Accept fitting a trap or an anti-suck-back device between the delivery tube and the trough (1).	**4**
(v) One other safety precaution	*2 marks for the precaution, 2 for the explanation.* Any one of: wear safety goggles, since hot glass and the alkaline catalyst can injure the eyes; keep the ethanol bottle well away from the flame, as ethanol is highly flammable; heat the catalyst strongly but the ethanol only gently and intermittently, so that vapour is not driven off faster than it can react; work in a well-ventilated room or fume cupboard, since ethene is flammable and forms explosive mixtures with air; do not collect the gas near a naked flame.	**4**
(vi) Observation	A yellow, smoky or sooty flame, with black carbon (soot) deposited on any surface held in it.	**3**
(vii) Complete combustion	$\mathbf{C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O}$ *2 marks for reactants and products, 2 for balancing.*	**4**

(b) Poly(ethene) (11 marks)

Part	Acceptable Answer(s)	Marks
(i) Name of the polymer	**Poly(ethene).** Accept polythene or polyethylene.	**2**

Part	Acceptable Answer(s)	Marks
(ii) Three repeating units	–CH_2–CH_2–CH_2–CH_2–CH_2–CH_2– drawn out with all atoms and bonds, or the repeating unit shown three times, with open continuation bonds at each end. *2 marks for the correct repeating unit, 2 for three of them joined with open bonds at both ends.*	**4**
(iii) Non-biodegradability	The polymer is a long saturated hydrocarbon chain held together by strong non-polar C–C and C–H covalent bonds (2). It has no functional groups and no polar sites for enzymes or water to attack, so micro-organisms have no mechanism to break it down and it cannot be hydrolysed (3).	**5**

(c) Four alkene isomers of C_4H_8 (12 marks)

3 marks per isomer × 4 = 12 marks (2 for the structure + 1 for the IUPAC name). The question requires molecular structures including all atoms and bonds, so the structure marks are available only for a displayed structure showing every carbon, every hydrogen and every bond. The table below identifies the four isomers; it does not show the required form of the answer.

Part	Acceptable Answer(s)	Marks
Isomer 1	CH_2=CH–CH_2–CH_3 — **but-1-ene**	**3**
Isomer 2	CH_3–CH=CH–CH_3 with both methyl groups on the same side of the double bond — **cis-but-2-ene**	**3**
Isomer 3	CH_3–CH=CH–CH_3 with the methyl groups on opposite sides of the double bond — **trans-but-2-ene**	**3**
Isomer 4	CH_2=C(CH_3)–CH_3 — **2-methylpropene** (accept methylpropene)	**3**

Cyclobutane and methylcyclopropane have the molecular formula C_4H_8 but are not alkenes, and earn nothing here.

Question 4 — 50 marks

Candidates answer any five of Questions 2 to 7. Each carries 50 marks.

Indicative mark allocation: (i) 5 · (ii) 3 · (iii) 2 · (iv) 4 · (v) 2 · (vi) 4 · (vii) 5 · (viii) 5 · (ix) 5 · (x) 5 · (xi) 3 · (xii) 7 = 50 marks. Parts (vii) to (x) form a single chain; error carried forward applies in full through it.

Part	Acceptable Answer(s)	Marks
(i) Preparing the burette	*1 mark per step, to a maximum of 5.* Rinse the burette with deionised water; rinse it with a little of the diluted vinegar solution and discard the rinsings, so that no water is left to dilute the solution; clamp it vertically; close the tap and fill above the zero mark using a funnel; open the tap briefly to fill the jet below the tap and expel any air bubble; run the level down to zero, or record the initial reading; remove the funnel before reading; take the reading from the bottom of the meniscus at eye level.	**5**
(ii) Purpose of the buffer	A buffer resists change in pH, so its value is known and stable (1); the probe is placed in it to calibrate the meter against that known value before the titration, so that the readings taken during the titration are accurate (2).	**3**
(iii) Type of titration	**Weak acid – strong base**	**2**
(iv) Justification	The curve begins at about pH 13, which indicates a strong base in the flask (2), and the steep section is centred well above pH 7, at about pH 8.7, which is where the equivalence point of a weak acid with a strong base lies because the salt formed is itself slightly basic (2). Accept reference to the final pH of about 3, consistent with excess weak acid rather than excess strong acid.	**4**
(v) Indicator	**o-cresolphthalein (pH range 8.2 – 9.8)**	**2**
(vi) Justification	The equivalence point lies at about pH 8.7, within the steep, near-vertical section of the curve, and o-cresolphthalein's range of 8.2 to 9.8 brackets it, so the indicator changes colour sharply at the end point, with one drop of acid taking the pH right through its range (3). Methyl orange (3.1 – 4.4) changes far down the shallow tail and indigo carmine (11.4 – 13.0) changes early in the shallow section before the drop, so both would be badly out; bromothymol blue (6.0 – 7.6) lies below the equivalence point, so its colour change would come only after excess acid had been added, giving a late end point (1).	**4**
(vii) Moles of NaOH	M(NaOH) = 40.0, so 1.8 g is 0.045 mol in 500.0 cm^3, a concentration of 0.09 M (3); in 25.0 cm^3, 0.045 × 25.0 ÷ 500.0 = **2.25×10^{-3} mol** (2).	**5**

Part	Acceptable Answer(s)	Marks
(viii) Moles of acid per cm^3	Average of the two accurate titrations = (10.9 + 10.8) ÷ 2 = 10.85 cm^3 (2). The equation is 1 : 1, so the titre contains 2.25×10^{-3} mol (1), and per cm^3 that is $2.25 \times 10^{-3} \div 10.85 =$ **2.07×10^{-4} mol cm^{-3}** (2). The approximate titration is excluded from the average; a candidate who includes it, giving 10.93 cm^3, loses the averaging mark but carries the error forward.	**5**
(ix) Concentration of the vinegar	Diluted solution: $2.07 \times 10^{-4} \times 1000 = 0.207$ moles per litre (2). The vinegar was diluted from 25.0 cm^3 to 100.0 cm^3, a factor of 4, so the undiluted vinegar is $0.207 \times 4 =$ **0.829 moles per litre** (3). Accept 0.83.	**5**
(x) Concentration in % w/v	M(CH_3COOH) = 60.0, so $0.829 \times 60.0 = 49.8$ g per litre (3), which is 4.98 g per 100 cm^3 = **4.98% w/v** (2). Accept 5.0% w/v.	**5**
(xi) Standardisation	Finding the exact concentration of a solution by titrating it against a primary standard — a solution of accurately known concentration made up from a pure, stable substance. Sodium hydroxide absorbs water and carbon dioxide from the air, so it cannot be weighed out accurately and its solution must be standardised before use.	**3**
(xii) Inductive effect and resonance	*3 marks for the inductive effect with its diagram, 3 for resonance with its diagram, 1 for the conclusion.* In ethanoic acid the two oxygen atoms are strongly electronegative and draw electron density away from the O–H bond through the sigma framework. The diagram should show δ− on the oxygen atoms and δ+ on the carbonyl carbon and the hydroxyl hydrogen, with arrows along the bonds indicating the pull. The O–H bond is weakened, so the proton is lost more readily. In the ethanoate ion the negative charge is not localised on one oxygen: the two carbon-oxygen bonds are identical and the charge is spread equally over both oxygen atoms. Show this either as two resonance structures joined by a double-headed arrow, or as a single delocalised structure with dashed bonds and half a negative charge on each oxygen. The delocalisation stabilises the ion, so its formation is favoured and ethanoic acid is appreciably more acidic than a comparable alcohol.	**7**

Examiner note: *the calculated strength of 4.98% w/v agrees with commercial vinegar, which is typically 4 to 8% w/v. A candidate who sense-checks the answer against that should be credited for the observation where a part invites comment.*

Question 5 — 50 marks

Candidates answer any five of Questions 2 to 7. Each carries 50 marks.

Indicative mark allocation: (a) 6 · (b)(i) 4 · (b)(ii) 3 · (b)(iii) 3 · (c)(i) 2 · (c)(ii) 2 · (c)(iii) 6 · (d)(i) 5 · (d)(ii) 4 · (d)(iii) 4 · (e) 11 = 50 marks.

(a) Labelling the three alcohol groups (6 marks)

2 marks per correct label × 3 = 6 marks. The structure printed is $CH_3–CH(OH)–CH_2–C(OH)(CH_3)–CH_2OH$.

Part	Acceptable Answer(s)	Marks
1 — primary	The $–CH_2OH$ group at the right-hand end: its carbon is attached to only one other carbon atom.	**2**
2 — secondary	The OH on the second carbon from the left: its carbon is attached to two other carbon atoms.	**2**
3 — tertiary	The OH on the carbon bearing the CH_3 branch: its carbon is attached to three other carbon atoms.	**2**

(b) Oxidation of alcohols (10 marks)

Part	Acceptable Answer(s)	Marks
(i) Primary alcohols	An **aldehyde**, and with continued oxidation a **carboxylic acid**. Both are required for full marks; under the conditions described, with acidified permanganate, oxidation normally proceeds to the carboxylic acid.	**4**
(ii) Secondary alcohols	A **ketone**	**3**
(iii) Tertiary alcohols	**None** — tertiary alcohols are not oxidised under these conditions, because the carbon bearing the OH group has no hydrogen atom attached to it.	**3**

(c) Reduction and catalysis (10 marks)

Part	Acceptable Answer(s)	Marks
(i) Reducing agent	**Hydrogen** (H_2)	**2**
(ii) Catalyst	**Nickel.** Accept platinum or palladium.	**2**
(iii) Surface adsorption	Reactant molecules are adsorbed onto active sites on the surface of the solid catalyst (2). Adsorption weakens the bonds within the adsorbed molecules and holds them close together in the right orientation to react, which lowers the activation energy (3). The reaction takes place on the surface, and the product molecules are then desorbed, freeing the active site for further reactant molecules (1).	**6**

The question pairs a reducing agent with a catalyst, and part (iii) then asks about the surface adsorption mechanism, so hydrogen with a transition metal catalyst is the intended answer. Accept sodium borohydride or lithium aluminium hydride at (i) only where the candidate's answer to (ii) is consistent with the reagent named; neither requires a heterogeneous catalyst.

(d) Propan-1-ol and esters (13 marks)

Part	Acceptable Answer(s)	Marks
(i) Acting as an acid	It donates a proton from its hydroxyl group: **$CH_3CH_2CH_2OH \rightarrow CH_3CH_2CH_2O^- + H^+$** (3) A proton donor is an acid on the Brønsted-Lowry definition, and the propoxide ion left behind is its conjugate base (2). Accept the reaction with sodium metal, $2CH_3CH_2CH_2OH + 2Na \rightarrow 2CH_3CH_2CH_2O^-Na^+ + H_2$, where the alcohol supplies the hydrogen.	**5**
(ii) Structure of propyl methanoate	H–C(=O)–O–CH_2–CH_2–CH_3 drawn out with every atom and bond shown. *2 marks for the ester linkage including the C=O, 2 for the correct propyl group with all hydrogens.*	**4**
(iii) Two structural isomers	*2 marks each.* **Ethyl ethanoate** and **methyl propanoate**. Accept propan-2-yl methanoate (isopropyl methanoate). All have the molecular formula $C_4H_8O_2$.	**4**

(e) Mass of propan-1-ol vapour (11 marks)

Part	Acceptable Answer(s)	Marks
Working	PV = nRT, with P = 1.013×10^5 Pa, V = 77.0 cm^3 = 7.70×10^{-5} m^3, T = 100.0 °C = 373 K and R = 8.31 J K^{-1} mol^{-1}. *3 marks for the equation, 2 for the conversions.*	**5**
Answer	n = $(1.013 \times 10^5 \times 7.70 \times 10^{-5}) \div (8.31 \times 373) = 7.80 \div 3100 = 2.52 \times 10^{-3}$ mol (3) M(C_3H_8O) = 60.0, so mass = $2.52 \times 10^{-3} \times 60.0$ = **0.151 g** (2, plus 1 for the unit). Accept 0.15 g.	**6**

A candidate who omits the conversion of cm^3 to m^3, or of °C to K, loses the conversion marks but keeps the method marks.

Question 6 — 50 marks

Candidates answer any five of Questions 2 to 7. Each carries 50 marks.

Indicative mark allocation: (a)(i) 3 · (a)(ii) 2 · (a)(iii) 3 · (a)(iv) 4 · (a)(v) 4 · (a)(vi) 4 · (a)(vii) 5 · (a)(viii) 4 · (a)(ix) 4 · (b)(i) 2 · (b)(ii) 4 · (b)(iii) 4 · (b)(iv) 7 = 50 marks.

(a) The lithium-ion cell (33 marks)

Part	Acceptable Answer(s)	Marks
(i) Secondary cell	A cell that can be recharged: the reaction in the cell is reversible, so passing a current through it in the opposite direction regenerates the original reactants.	**3**
(ii) Allotrope	**Graphite**	**2**
(iii) Galvanic cell	A cell in which a spontaneous redox reaction produces an electric current, converting chemical energy into electrical energy.	**3**
(iv) Function of the barrier	It keeps the two electrodes physically apart so that they cannot touch and short-circuit the cell (2), while remaining porous to lithium ions so that they can pass between the electrodes and complete the internal circuit (2).	**4**
(v) Oxidation half-reaction	$\mathbf{LiC_6 \rightarrow C_6 + Li^+ + e^-}$	**4**
(vi) Reduction half-reaction	$\mathbf{CoO_2 + Li^+ + e^- \rightarrow LiCoO_2}$	**4**
(vii) Lithium and water	$\mathbf{2Li + 2H_2O \rightarrow 2LiOH + H_2}$ *3 marks for reactants and products, 2 for balancing.*	**5**
(viii) Function of the electrolyte	It allows ions to move between the two electrodes, carrying charge through the inside of the cell and completing the circuit (3), while not conducting electrons, which are forced to travel through the external circuit instead (1).	**4**
(ix) Environmental impact	Either direction is acceptable, developed. **Negative:** mining lithium and cobalt consumes very large volumes of water, damages landscapes and habitats and produces toxic waste; spent cells sent to landfill can leach heavy metals, and they present a fire risk. **Positive:** lithium-ion cells make electric vehicles and grid-scale storage of wind and solar energy practical, displacing fossil fuels and reducing carbon dioxide emissions.	**4**

(b) Synthesis of benzoic acid (17 marks)

Part	Acceptable Answer(s)	Marks
(i) Suitable base	**Sodium hydroxide.** Accept potassium hydroxide or sodium carbonate.	**2**

Part	Acceptable Answer(s)	Marks
(ii) Colour changes	The solution begins **purple** (manganate(VII), Mn^{7+}), turns **brown** as manganese(IV) oxide forms (Mn^{4+}), and finally becomes **colourless** as Mn^{2+} is produced. Award 2 where only the first and last are given.	**4**
(iii) Confirming purity	Determine the melting point and compare it with the literature value for benzoic acid, 122 °C (2): a pure sample melts sharply at the correct temperature, whereas an impure one melts over a range and below it (2). Accept thin-layer chromatography showing a single spot.	**4**
(iv) Percentage yield	Mass of phenylmethanol = 4.5 × 1.04 = 4.68 g (2) $M(C_6H_5CH_2OH)$ = 108.0, so n = 4.68 ÷ 108.0 = 0.0433 mol (2) The ratio is 1 : 1, so the theoretical yield of benzoic acid = 0.0433 × 122.0 = 5.29 g (2) % yield = 3.6 ÷ 5.29 × 100 = **68.1%** (1). Accept 68%.	**7**

Examiner note: *the question specifies basic conditions and also directs the sequence $Mn^{7+} \rightarrow Mn^{4+} \rightarrow Mn^{2+}$. In practice, permanganate reduced under basic conditions stops at manganese(IV) oxide; reduction to Mn^{2+} requires acidic conditions, which are introduced when the mixture is acidified to precipitate the benzoic acid. Mark the colour sequence as printed, and credit a candidate who notes the point.*

Question 7 — 50 marks

Candidates answer any five of Questions 2 to 7. Each carries 50 marks.

Indicative mark allocation: (i) 4 · (ii) 7 · (iii) 8 · (iv) 5 · (v) 3 · (vi) 5 · (vii) 2 · (viii) 5 · (ix) 3 · (x) 8 = 50 marks.

Part	Acceptable Answer(s)	Marks
(i) Why the mass decreased	Carbon dioxide gas is produced by the reaction (2) and escapes from the open flask into the air, so the mass of the contents falls by the mass of gas lost (2).	**4**
(ii) Reactant in excess	n(HCl) = 1.5 × 0.0500 = 0.0750 mol (2) M(Li_2CO_3) = 73.8, so n = 3.00 ÷ 73.8 = 0.0407 mol (2) The equation requires 2 mol of HCl per mol of Li_2CO_3, so 0.0407 mol would need 0.0813 mol of HCl, and only 0.0750 mol is available (2) The acid is therefore the limiting reactant and the **lithium carbonate is in excess** (1)	**7**
(iii) Plotting the graph	*2 marks for axes correctly labelled with quantity and unit, with the mass axis beginning at 54 g as instructed; 2 for suitable scales using more than half the grid; 3 for the plotted points; 1 for a smooth curve of best fit.* Deduct 1 of the 3 plotting marks for each misplotted point, to a minimum of zero. The curve falls steeply at first and flattens to a constant 54.35 g from 80 s.	**8**
(iv) Initial rate	A tangent drawn to the curve at t = 0, with its gradient calculated: the mass falls by about 0.68 g over the first 10 s and the tangent at the origin is steeper, giving approximately **0.08 g s^{-1}**. *3 marks for the tangent, 1 for the gradient, 1 for the unit.* Accept 0.068 to 0.10 g s^{-1}. A candidate who gives the average over the first 10 s, 0.068 g s^{-1}, without drawing a tangent earns a maximum of 3.	**5**
(v) Curve at higher temperature	A curve falling more steeply from the start (2) and levelling off at the **same final mass of 54.35 g**, reached sooner (1). A curve ending at a different final mass is incorrect: temperature changes the rate, not the amount of carbon dioxide the reactants can produce.	**3**
(vi) Density of the acid	The initial reading of 56.00 g was taken after the 3.00 g of solid had been added, so the acid alone has a mass of 56.00 − 3.00 = 53.00 g (3). Density = 53.00 ÷ 50.0 = **1.06 g cm^{-3}** (1, plus 1 for the unit).	**5**
(vii) Endothermic or exothermic	**Exothermic**	**2**
(viii) Reaction profile	*2 marks for the products drawn at a lower energy than the reactants; 2 for the activation energy hump above the reactants, labelled E_a from the reactants to the peak; 1 for ΔH marked as the drop from reactants to products and labelled negative.*	**5**
(ix) Flame colour	**Crimson** (red)	**3**

Part	Acceptable Answer(s)	Marks
(x) Carbonate or hydrogencarbonate	*4 marks for the reagent, 4 for the observation and what it shows.* Dissolve the solid in water and add magnesium sulfate solution: a **white precipitate** of magnesium carbonate forms immediately at room temperature with a carbonate, whereas a hydrogencarbonate gives no precipitate unless the mixture is heated. **Also accept** heating the dry solid and testing the gas given off: a hydrogencarbonate decomposes readily at a low temperature to release carbon dioxide, which turns limewater milky, whereas a carbonate requires much stronger heating.	**8**

Examiner note: *adding dilute acid and testing for carbon dioxide with limewater does not distinguish the two ions, since both effervesce and both give carbon dioxide. Award a maximum of 2 for that answer.*
This part carries 8 marks against the 6 awarded for the nitrate test at 2(b)(iv), although both have the same reagent-and-observation shape: here the candidate must find a test that discriminates between two chemically similar anions rather than confirm the presence of one, and the printed answer space is correspondingly larger.

This marking scheme is indicative. The paper prints a total of 50 marks for each question and no sub-part marks, so all internal splits are those of this scheme; they reconcile to 50 marks for each question and to 300 marks for the six questions a candidate answers. Examiners should use professional judgement when awarding marks and should credit all reasonable responses not listed here. Prepared by SimpleStudy for study purposes; not an official State Examinations Commission document.