SimpleStudy

PRACTICE MARKING SCHEME

LEAVING CERTIFICATE · HIGHER LEVEL · SAMPLE PAPER 1 · 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 1 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(c) to page 80, 3(a)(i) to page 81 — 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.
- **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.

Paper Structure

Question 1	**50 marks**	Compulsory. Emission spectra, Hess's law, ionisation energy, intermolecular forces and preparing a standard solution of iron(II).
Question 2	**50 marks**	Alcohols and their classification, shapes of molecules, esterification and surfactants.
Question 3	**50 marks**	Ionic bonding and solubility, electrolysis and galvanic cells, and neutralisation calculations.

Question 4	**50 marks**	Rates of reaction from a graph, catalysis, a gas volume calculation and a redox equation.
Question 5	**50 marks**	Water treatment, carbon emissions, and chemical equilibrium including Le Châtelier's principle.
Question 6	**50 marks**	Acids and bases, pH curves and a titration calculation.
Question 7	**50 marks**	Geometric isomerism, combustion, the laboratory preparation of ethene and an addition mechanism.
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(e), 2(c)(ii), 3(b)(ii), 5(a)(i), 7(b)(i) and 7(b)(iii) — are marked by required elements rather than holistically, which suits a practical description or a reaction mechanism better than a band descriptor. 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) 2 · (a)(ii) 2 · (a)(iii) 2 · (a)(iv) 3 · (a)(v) 3 · (b) 9 · (c)(i) 4 · (c)(ii) 8 · (d) 8 · (e) 9 = 50 marks.

(a)(i)–(iii) State the physical quantity represented (6 marks)

2 marks per part × 3 = 6 marks.

Part	Acceptable Answer(s)	Marks
(i) E_m	The energy of the higher energy level, that is the energy of the excited state the electron falls from.	**2**
(ii) E_n	The energy of the lower energy level the electron falls to.	**2**
(iii) f	The frequency of the radiation (the photon) emitted.	**2**

(a)(iv)–(v) Identify elements X and Y (6 marks)

3 marks per element × 2 = 6 marks. The question asks only for the element, so award the 3 marks for the correct element alone; no supporting reason is required. A reason is creditable only where a candidate's named element differs from the expected answer but follows from the reason given.

Part	Acceptable Answer(s)	Marks
(iv) X	**Copper** (Cu)	**3**
(v) Y	**Calcium** (Ca)	**3**

Examiner note: *the booklet carries no table of emission spectra, so candidates identify these from characteristic lines or from the flame colours they have met. X shows three closely spaced green lines at approximately 509, 515 and 521 nm — the copper triplet — consistent with copper's blue-green flame. Y shows violet-blue lines at approximately 413, 435, 440 and 447 nm together with orange-red lines at approximately 608, 634 and 656 nm, consistent with calcium's brick-red flame. The printed spectrum spans roughly 358 to 657 nm. Within that range, calcium is the only one of the usual flame-test elements that accounts for both the violet-blue and the orange-red groups. Barium is excluded because its strongest line, at 553 nm, lies inside the printed range and is absent; strontium is excluded because its in-range lines at 460.7 nm and in the 481–496 nm group are likewise absent, and nothing in Y corresponds to them. Strontium's strong lines at 688 and 707 nm fall outside the figure and play no part in the reasoning either way. Examiners should be aware that calcium's strongest line, at 422.7 nm, is also absent, so the identification rests on the pattern as a whole rather than on any single line.*

(b) Calculate ΔH for $ClF + F_2 \rightarrow ClF_3$ using Hess's law (9 marks)

3 marks for a correct combination of the three given equations + 3 marks for the corresponding manipulation of the ΔH values + 2 marks for the arithmetic + 1 mark for the unit. Accept any valid route, including an

energy cycle drawn as a diagram. A correct answer with no supporting work earns a maximum of 5, in line with the warning printed on the paper.

Part	Acceptable Answer(s)	Marks
Method	Take equation (2) as written, reverse equation (3) and reverse equation (1); add, then halve. $2ClF + O_2 \rightarrow Cl_2O + OF_2$ (+205.6) $Cl_2O + 3OF_2 \rightarrow 2ClF_3 + 2O_2$ (−533.4) $O_2 + 2F_2 \rightarrow 2OF_2$ (+49.1) Sum: $2ClF + 2F_2 \rightarrow 2ClF_3$, $\Delta H = -278.7$ kJ	**6**
Answer	$-278.7 \div 2 =$ **$\Delta H = -139.35$ kJ mol^{-1}** (accept −139 to −139.4)	**3**

(c)(i) What is meant by the first ionisation energy of an element (4 marks)

2 marks for the core statement — the energy required to remove an electron from an atom — plus 1 mark each for any two of the three qualifiers: the atom is in the gaseous state; it is a neutral atom in its ground state; the electron removed is the most loosely bound or outermost one.

Part	Acceptable Answer(s)	Marks
Definition	The minimum energy required to remove the most loosely bound electron from a neutral gaseous atom in its ground state. Accept "per mole of atoms"; accept wording that refers to forming a positive ion.	**4**

(c)(ii) Identify and explain the exceptions in the second period (8 marks)

4 marks per exception × 2 = 8 marks (1 mark for identifying the pair + 1 mark for quoting the values from page 80 + 2 marks for the explanation). Both exceptions are required; a candidate who identifies both pairs with no explanation earns 2 in total.

Part	Acceptable Answer(s)	Marks
Boron lower than beryllium	B is 801 kJ mol^{-1} against Be at 900 kJ mol^{-1}. Boron's outermost electron is in the 2p sublevel, which is higher in energy and further from the nucleus than the 2s sublevel, and it is shielded by the 2s electrons, so less energy is needed to remove it.	**4**
Oxygen lower than nitrogen	O is 1314 kJ mol^{-1} against N at 1402 kJ mol^{-1}. In oxygen two of the 2p electrons occupy the same orbital and repel one another, so one is removed more easily; nitrogen's half-filled $2p^3$ arrangement, with all three electrons in separate orbitals, is comparatively stable.	**4**

(d) Diagram explaining why propanone mixes easily with water (8 marks)

2 marks for the structure of propanone showing the C=O group + 1 mark for the structure of water + 2 marks for the dipoles marked + 3 marks for the intermolecular attraction drawn between the correct specific atoms.

Part	Acceptable Answer(s)	Marks
Structures	One molecule of propanone, CH_3COCH_3, with the carbonyl group drawn as C=O; one molecule of water drawn bent, H–O–H.	**3**

Part	Acceptable Answer(s)	Marks
Dipoles	δ− on the carbonyl oxygen and on the water oxygen; δ+ on the carbonyl carbon and on the water hydrogens. Accept arrows along the bonds pointing towards the oxygen in place of the symbols.	**2**
Intermolecular force	A dotted line drawn from a δ+ hydrogen atom of the water molecule to the δ− oxygen atom of the propanone molecule, labelled as a hydrogen bond or as a dipole-dipole attraction.	**3**

The attraction must be shown between the correct specific atoms, as the question requires; a line drawn between the two molecules generally earns 1 of the 3 marks. No marks are lost for the orientation of the molecules on the page.

(e) Describe how to make up an exact volume of a solution of iron(II) from the tablets (9 marks)

1 mark per element, to a maximum of 9. Apparatus marks are available within the nine. The question asks the candidate to identify all relevant chemicals and apparatus and to describe how they were used, so a list of apparatus with no procedure earns a maximum of 4.

Part	Acceptable Answer(s)	Marks
Expected elements	• Crush the five tablets using a mortar and pestle. • Dissolve the powder in dilute sulfuric acid, which keeps the iron as Fe^{2+} and prevents it oxidising. • Warm gently and stir with a glass rod to dissolve as much as possible. • Filter to remove the insoluble binder, collecting the filtrate. • Transfer the filtrate through a funnel into a volumetric flask of stated volume, for example 250 cm^3. • Rinse the beaker, the glass rod and the filter paper into the flask so that no iron is lost. • Add deionised water to make up to the calibration mark. • Add the last of the water dropwise with a teat pipette, with the bottom of the meniscus on the mark at eye level. • Stopper the flask and invert it repeatedly to mix the solution thoroughly.	**9**

Accept any other valid step or item of apparatus. This list is not exhaustive.

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) 3 · (a)(iv) 4 · (a)(v) 3 · (a)(vi) 5 · (b)(i) 3 · (b)(ii) 5 · (b)(iii) 2 · (b)(iv) 3 · (c)(i) 3 · (c)(ii) 9 · (c)(iii) 3 = 50 marks.

(a)(i)–(v) The two alcohols (17 marks)

Classification parts carry 2 marks for the classification + 2 marks for the justification.

Part	Acceptable Answer(s)	Marks
(i) Name of A	**hexan-2-ol**	**3**
(ii) Class of A	**Secondary** (2), because the carbon atom carrying the OH group is attached to two other carbon atoms (2).	**4**
(iii) Name of B	**3-methylpentan-3-ol**	**3**
(iv) Class of B	**Tertiary** (2), because the carbon atom carrying the OH group is attached to three other carbon atoms (2).	**4**
(v) Formula of B	$CH_3CH_2C(CH_3)(OH)CH_2CH_3$. Accept $CH_3CH_2C(OH)(CH_3)CH_2CH_3$.	**3**

(a)(vi) Why the bond angle at the oxygen atom is less than 180° (5 marks)

Part	Acceptable Answer(s)	Marks
Explanation	The oxygen atom has four pairs of electrons around it, two bonding pairs and two lone pairs (2). These pairs repel one another and take up a roughly tetrahedral arrangement rather than a linear one (1). The lone pairs repel more strongly than the bonding pairs, closing the bond angle further, to about 104.5° (2).	**5**

(b) The ester (13 marks)

Part	Acceptable Answer(s)	Marks
(i) Name of ester	**methyl ethanoate**	**3**
(ii) Structure	$CH_3–C(=O)–O–CH_3$ drawn out in full, with the C=O double bond and the C–O–C linkage shown and every hydrogen atom and bond drawn. *3 marks for the correct skeleton including the C=O and the C–O–C linkage, 2 marks for all atoms and bonds shown.*	**5**
(iii) Other product	**Water** (H_2O)	**2**
(iv) Advantage of reflux	The mixture can be heated for a prolonged period, which increases the rate and the yield, without losing the volatile reactants or the volatile product, because the vapours condense and run back into the flask.	**3**

(c) Soaps and surfactants (15 marks)

Part	Acceptable Answer(s)	Marks
(i) Other reactant	**Sodium hydroxide** (NaOH). Accept any named strong alkali, including potassium hydroxide.	**3**
(ii) How soaps work	A soap molecule has two distinct parts (1): a long non-polar hydrocarbon tail, which is hydrophobic and dissolves in grease and oil (3), and an ionic head, which is hydrophilic and dissolves in water (3). The soap lowers the surface tension of the water so that it wets the surface (1). The tails embed themselves in the grease while the heads face outwards into the water; agitation lifts the grease away as droplets surrounded by soap molecules, called micelles, which stay suspended in the water and are rinsed away (1).	**9**
(iii) Other use	Any one of: detergents and washing-up liquids; shampoos and personal care products; emulsifiers in food; wetting agents in paints and inks; fabric conditioners; froth flotation in mineral processing; adjuvants in agricultural sprays.	**3**

Accept any other valid application. This list is not exhaustive.

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) 6 · (a)(iii) 5 · (b)(i) 5 · (b)(ii) 9 · (c)(i) 6 · (c)(ii) 6 · (c)(iii) 8 = 50 marks.

(a) Magnesium chloride (16 marks)

Part	Acceptable Answer(s)	Marks
(i) Why ionic	From page 81 of the booklet, magnesium has an electronegativity of 1.31 and chlorine 3.16 (2); the difference is 1.85 (1); a difference of 1.7 or greater indicates that the bonding is predominantly ionic, with electrons transferred from the magnesium atom to the chlorine atoms rather than shared (2).	**5**
(ii) Cl^- configuration	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ (3). It is stable because the outermost energy level is now full, an octet in the third level, giving the ion the same electron arrangement as the noble gas argon (3).	**6**
(iii) Why soluble	Magnesium chloride is ionic and water is a polar molecule (1). The δ− oxygen of the water molecules is attracted to the Mg^{2+} ions and the δ+ hydrogens to the Cl^- ions (2). These ion-dipole attractions release enough energy to overcome the forces holding the crystal lattice together, so the lattice breaks up and the hydrated ions disperse through the water (2).	**5**

(b) Electrochemistry (14 marks)

Part	Acceptable Answer(s)	Marks
(i) Anode or cathode	The **cathode** (2). Magnesium ions are positively charged and are attracted to the negative electrode, where they gain electrons and are reduced: $Mg^{2+} + 2e^- \rightarrow Mg$ (3). Reduction takes place at the cathode.	**5**
(ii) Galvanic cell	Marked by required elements: • Two different metals, each in a solution of its own ions, form two half-cells (1). • They are joined by an external wire and by a salt bridge (1). • The more reactive metal is **oxidised** at the anode, losing electrons and entering solution as ions, for example $Zn \rightarrow Zn^{2+} + 2e^-$ (3, of which 1 for naming the species oxidised). • The electrons travel through the external circuit, and this flow of electrons is the electric current (2). • At the cathode the ions of the less reactive metal are **reduced**, gaining those electrons and depositing as metal, for example $Cu^{2+} + 2e^- \rightarrow Cu$ (2, of which 1 for naming the species reduced). • The salt bridge allows ions to move between the half-cells, completing the circuit and keeping the solutions electrically neutral (1, within the total).	**9**

Any correct pair of metals is acceptable. The question requires both the species oxidised and the species reduced to be named; a candidate who omits one loses that naming mark.

(c) Neutralisation calculations (20 marks)

Using the relative atomic masses in the booklet, $M(Mg(OH)_2) = 58.3$ and $n(Mg(OH)_2) = 22.0 \div 58.3 = 0.3774$ mol. Error carried forward applies throughout.

Part	Acceptable Answer(s)	Marks
(i) Mass of Mg	$0.3774 \times 24.3 =$ **9.17 g** (accept 9.2 g). *2 marks for the molar mass, 2 for the moles, 2 for the mass.* Accept the proportion route, $24.3 \div 58.3 \times 22.0$.	**6**
(ii) Volume of acid	From the equation $n(HCl) = 2 \times 0.3774 = 0.7547$ mol; volume $= 0.7547 \div 1.8 = 0.419$ litres = **419 cm³** (accept 420 cm^3). *2 marks for the 1 : 2 ratio, 2 for the moles of HCl, 1 for the volume, 1 for the unit.*	**6**
(iii) Concentration	$n(MgCl_2) = 0.3774$ mol. The solution volume is the acid added plus the water formed: $n(H_2O) = 0.7547$ mol, mass 13.6 g, which at a density of 1.0 g cm^{-3} occupies 13.6 cm^3. Total volume $= 419 + 13.6 = 432.6$ cm^3. Concentration $= 0.3774 \div 0.4326 =$ **0.87 M**. **Also accept** 0.90 M from a candidate who uses the volume of acid alone, to a maximum of 6 marks: the density is given in the question in order to be used, but the omission is a single conceptual error rather than an arithmetic one.	**8**

Question 4 — 50 marks

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

Indicative mark allocation: (a)(i) 5 · (a)(ii) 6 · (a)(iii) 5 · (a)(iv) 4 · (a)(v) 4 · (b) 12 · (c)(i) 4 · (c)(ii) 10 = 50 marks.

(a) Rate of reaction from the graph (24 marks)

Read from the printed graph: the volume of oxygen is 70 cm^3 at 10 s, 105 cm^3 at 20 s, and the curve levels off at 132 cm^3 from about 50 s.

Part	Acceptable Answer(s)	Marks
(i) Average rate	105 ÷ 20 = **5.25 cm^3 s^{-1}**. *2 marks for reading the graph, 2 for dividing by the time, 1 for the unit.* Accept any reading between 100 and 110 cm^3, giving 5.0 to 5.5 cm^3 s^{-1}.	**5**
(ii) Instantaneous rate at 20 s	A tangent drawn to the curve at t = 20 s, with its gradient calculated from two points on the tangent, giving approximately **2.5 cm^3 s^{-1}**; accept 2.0 to 3.0 where a tangent is drawn. *3 marks for drawing the tangent, 2 for the gradient calculation, 1 for the unit.* A bare numerical answer with no tangent drawn earns a maximum of 2.	**6**
(iii) Why the rate decreases	Hydrogen peroxide is used up as the reaction proceeds, so its concentration falls (3). With fewer reactant particles in the same volume there are fewer effective collisions per second, so the rate drops, and the curve levels off once all the H_2O_2 has decomposed (2).	**5**
(iv) More effective catalyst	A curve rising more steeply than the original (2) and levelling off at the **same final volume of 132 cm^3**, reached sooner (2). A curve that levels off at a higher volume is incorrect: a catalyst changes the rate, not the amount of product.	**4**
(v) Making it more effective	Increase the surface area of the catalyst — use it finely divided or powdered rather than in lumps, or spread it on a support or mesh (2) — so that more active sites are exposed and more reactant particles can be adsorbed at any moment (2).	**4**

(b) Volume of oxygen produced (12 marks)

Part	Acceptable Answer(s)	Marks
Working	5% w/v means 5 g per 100 cm^3, so 150 cm^3 contains 7.5 g of H_2O_2 (3). $M(H_2O_2)$ = 34.0, so n = 7.5 ÷ 34.0 = 0.2206 mol (3). From $2H_2O_2 \rightarrow 2H_2O + O_2$, $n(O_2)$ = 0.2206 ÷ 2 = 0.1103 mol (3).	**9**
Answer	V = 0.1103 × 22.4 litres per mole = **2.47 litres** (2470 cm^3). *2 marks for the calculation, 1 for the unit.*	**3**

(c) Redox reaction with iron(II) (14 marks)

Part	Acceptable Answer(s)	Marks
(i) Oxidation number	**−1**	**4**
(ii) Balanced equation	**$H_2O_2 + 2Fe^{2+} + 2H^+ \rightarrow 2Fe^{3+} + 2H_2O$** 10 marks for the fully balanced equation. Where it is not fully balanced: award 6 where the Fe and H_2O coefficients are both correct; 5 where the candidate sets out correct half-equations or a correct electron balance without completing the overall equation; 3 where only the Fe coefficients are correct.	**10**

Candidates may reach the answer by oxidation numbers — oxygen goes from −1 to −2, a gain of one electron each, so two Fe^{2+} ions are oxidised per molecule of H_2O_2 — or by inspection. Both are acceptable. The equation balances for charge as well as for atoms, +6 on each side.

Question 5 — 50 marks

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

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

(a) Water treatment (20 marks)

Part	Acceptable Answer(s)	Marks
(i) Flocculation	*3 marks for what it is, 3 marks for why it is carried out.* A chemical such as aluminium sulfate (alum) or a polyelectrolyte is added and the water stirred slowly, causing the tiny suspended particles to clump together into larger, heavier clusters called flocs. It is carried out because individual colloidal particles are too small and too light to settle out on their own; once aggregated they are heavy enough to sink during sedimentation and be removed, which clarifies the water and reduces the load on the later filtration stages.	**6**
(ii) Microplastics	*2 marks per route, any two.* Synthetic fibres shed from clothing in washing machines and carried out in wastewater; larger plastic litter breaking down in rivers and the sea; microbeads from cosmetics and toothpaste; particles from tyre and road wear washed off in surface run-off; spills of industrial plastic pellets; sewage sludge spread on land and washed into watercourses; degradation of plastic pipework.	**4**
(iii) UV treatment	*3 marks for what it is, 3 marks for why it is carried out.* The water is passed in a thin layer close to ultraviolet lamps. The UV radiation is absorbed by the DNA of bacteria, viruses and protozoa and damages it, so that the organisms can no longer reproduce or cause infection. It is carried out as a disinfection step, making the water microbiologically safe without adding any chemical to it.	**6**
(iv) Advantage over chlorination	No chemical is added, so there is no taste or odour and no risk of overdosing (2); and no disinfection by-products such as trihalomethanes are formed, which chlorination can produce where the water contains organic matter (2). Accept effectiveness against chlorine-resistant organisms such as *Cryptosporidium*.	**4**

Accept any other valid route or advantage. These lists are not exhaustive.

(b) Carbon emissions (7 marks)

Part	Acceptable Answer(s)	Marks
(i) Solar panels	The panels generate electricity on site from sunlight, with no fuel burned and no carbon dioxide released (2). That electricity displaces electricity the plant would otherwise draw from the grid, a share of which is generated by burning fossil fuels, so the emissions associated with each litre of water treated fall (2).	**4**

Part	Acceptable Answer(s)	Marks
(ii) One other way	Improve the efficiency of pumps and aeration, for example with variable-speed drives; reduce leakage so that less water has to be treated and pumped; generate biogas from sludge digestion and use it on site; install wind generation or buy certified renewable electricity; use gravity-fed distribution where the terrain allows; schedule pumping to off-peak periods.	**3**

The question excludes anything that would affect the quality of the water, so an answer based on reducing or omitting treatment steps earns nothing.

(c) Chemical equilibrium (23 marks)

Part	Acceptable Answer(s)	Marks
(i) Chemical equilibrium	The state reached in a reversible reaction when the rate of the forward reaction equals the rate of the reverse reaction (2), so that the concentrations of reactants and products remain constant even though both reactions continue — a dynamic equilibrium (2).	**4**
(ii) K_c expression	For $HOCl \rightleftharpoons H^+ + ClO^-$: $K_c = [H^+][ClO^-] \div [HOCl]$	**4**
(iii) Value of K_c	Since $[HOCl] = [ClO^-]$, those terms cancel and $K_c = [H^+]$ (3). $[H^+] = 10^{-7.53}$, so $\mathbf{K_c = 2.95 \times 10^{-8}}$ (3). Accept 2.9 or 3.0×10^{-8}. The unit is creditable but not required.	**6**
(iv) Le Châtelier's principle	When a system at equilibrium is subjected to a change in concentration, temperature or pressure, the position of equilibrium shifts in the direction that opposes, or minimises, that change.	**4**
(v) Effect of adding NaOCl	The pH **increases** (2). Sodium hypochlorite dissolves to give more ClO^-, raising the concentration of a product; by Le Châtelier's principle the equilibrium shifts to the left to oppose that increase, combining ClO^- with H^+ to form HOCl. The concentration of H^+ therefore falls and the pH rises (3).	**5**

Question 6 — 50 marks

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

Indicative mark allocation: (a)(i) 4 · (a)(ii) 4 · (a)(iii) 8 · (a)(iv) 4 · (a)(v) 4 · (a)(vi) 3 · (b)(i) 4 · (b)(ii) 4 · (b)(iii) 2 · (b)(iv) 3 · (b)(v) 4 · (b)(vi) 6 = 50 marks.

(a) Acids, bases and pH curves (27 marks)

Part	Acceptable Answer(s)	Marks
(i) Acid and base	An acid is a proton (H^+) donor; a base is a proton acceptor. Accept the Arrhenius pair, given that the stem names Arrhenius: an acid produces H^+ ions in water and a base produces OH^- ions. Both halves are required.	**4**
(ii) Strong and weak acid	A strong acid dissociates (ionises) completely in water, so effectively all of its molecules give up their protons; a weak acid dissociates only partially, forming an equilibrium in which most of the acid remains undissociated. Both halves are required.	**4**
(iii) Matching the curves ***2 marks per row***	strong acid – strong base: **D** strong acid – weak base: **C** weak acid – strong base: **A** weak acid – weak base: **B**	**8**
(iv) Weak acid – weak base	There is no sharp change of pH at the end point; the curve falls gradually, so the end point cannot be pinpointed (2), and no indicator changes colour over a sufficiently narrow pH range to mark it (2).	**4**
(v) pH meter rather than indicator	The meter gives a precise numerical value that can be recorded continuously throughout the titration, so the whole curve can be plotted (2), whereas universal indicator gives only an approximate value judged by matching a colour, which is subjective and can be obscured in coloured solutions (2).	**4**
(vi) Variable kept constant	Any one of: the concentration of the solutions; the volume of solution in the conical flask; the temperature; the size of the increments added; using the same meter, calibrated before each titration.	**3**

Examiner information only. *Acid is being added to base in all four titrations, so every curve falls. The starting pH distinguishes the base — about 12.9 for a strong base (A and D), about 11 for a weak base (B and C) — and the final pH distinguishes the acid, about 1 for a strong acid (C and D) and about 3 for a weak acid (A and B). The vertical sections confirm the assignment: D has a long sharp drop centred near pH 7, A's is centred near pH 9, C's near pH 5, and B has no sharp section at all. The printed axes carry no volume scale, so no part of a candidate's answer can depend on the volume of acid added, and none should be expected to refer to it.*

(b) Titration calculation (23 marks)

Part	Acceptable Answer(s)	Marks
(i) Standard solution	A standard solution has an accurately known concentration (2), and the calculation of the unknown concentration depends on it: without one accurately known value, no concentration can be determined from the titre (2).	**4**
(ii) Moles of XOH	$n = 0.08 \times 20.0 \div 1000 =$ **1.6×10^{-3} mol**. *2 marks for the method, 2 for the answer.*	**4**
(iii) Equipment	**Burette**	**2**
(iv) Moles of HA	The equation shows a 1 : 1 ratio, so $n(HA) =$ **1.6×10^{-3} mol**.	**3**
(v) Concentration of HA	$c = 1.6 \times 10^{-3} \div 0.0114 =$ **0.140 M** (accept 0.14 M).	**4**
(vi) pH of HA	$[H^+] = \sqrt{(K_a \times c)} = \sqrt{(1.74 \times 10^{-9} \times 0.140)} = \sqrt{(2.44 \times 10^{-10})} = 1.56 \times 10^{-5}$ (4). $pH = -\log_{10}(1.56 \times 10^{-5}) =$ **4.81** (2). Accept 4.8.	**6**

Error carried forward applies in full through this sequence: a candidate who uses an incorrect value from an earlier part correctly in a later one earns the later marks.

Question 7 — 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) 5 · (a)(iv) 6 · (a)(v) 5 · (a)(vi) 4 · (b)(i) 8 · (b)(ii) 5 · (b)(iii) 8 · (b)(iv) 2 = 50 marks.

(a) But-2-ene and geometric isomerism (27 marks)

Part	Acceptable Answer(s)	Marks
(i) Industrial use	Any one of: fuels, including petrol, diesel, kerosene, LPG and natural gas; feedstock for plastics and polymers; manufacture of other chemicals; solvents; lubricants.	**3**
(ii) Structure of cis-but-2-ene	Four carbons drawn with the C=C between C2 and C3, a methyl group and a hydrogen atom on each of those two carbons, and both methyl groups on the **same side** of the double bond. *2 marks for the correct skeleton with the double bond in the 2-position, 1 for all atoms and bonds shown, 1 for the cis arrangement.*	**4**
(iii) Similar heats of combustion	The two isomers have the same molecular formula and the same numbers and types of bonds (2); they burn to give exactly the same products in the same amounts, $4CO_2$ and $4H_2O$ (2); the only difference is the small difference in stability between the two arrangements about the double bond (1).	**5**
(iv) Combustion equation	**$C_4H_8 + 6O_2 \rightarrow 4CO_2 + 4H_2O$** *3 marks for correct reactants and products, 3 for balancing.*	**6**
(v) High activation energy	Converting one geometric isomer into the other requires rotation about the carbon-carbon double bond (2). The π bond is formed by the sideways overlap of p orbitals above and below the plane of the molecule; rotation would destroy that overlap, so the π bond has to be broken before rotation can occur, and breaking it requires a large input of energy (3).	**5**
(vi) But-1-ene	Geometric isomerism requires each of the doubly bonded carbon atoms to carry two different groups (2). In but-1-ene the terminal carbon of the double bond carries two hydrogen atoms, so interchanging them gives the same molecule and no separate cis and trans forms exist (2).	**4**

(b) Preparation of ethene and addition reactions (23 marks)

Part	Acceptable Answer(s)	Marks
(i) Labelled diagram *1 mark per feature*	• Ethanol absorbed on mineral wool or sand at the closed end of a hard-glass boiling tube, labelled. • The tube clamped horizontally, or sloping slightly downwards towards the delivery end. • Aluminium oxide, pumice or broken porous pot as the catalyst, in the middle of the tube and labelled. • A Bunsen burner heating the catalyst strongly, with the ethanol heated gently and intermittently. • A bung and delivery tube at the open end. • The delivery tube leading into a trough of water. • Ethene collected over water by downward displacement in an inverted test tube or gas jar. • A precaution against suck-back shown or labelled, for example removing the delivery tube from the water before the heating is stopped. • The first tube of gas discarded, because it is mostly displaced air. Maximum 8 marks.	**8**
(ii) Decolourising $KMnO_4$	Ethene is unsaturated and is oxidised across the double bond to ethane-1,2-diol (2); in doing so it reduces the manganate(VII) ion, so the purple MnO_4^- is converted to the colourless Mn^{2+} ion under acidic conditions (2); the loss of colour is therefore a test for unsaturation (1).	**5**
(iii) Mechanism	Marked by required elements: • As the chlorine molecule approaches the electron-rich double bond, the Cl–Cl bond becomes polarised, the nearer chlorine atom taking a δ+ charge (2). • The π electrons of the double bond attack that δ+ chlorine atom, shown by a curly arrow from the double bond to the chlorine (2). • The Cl–Cl bond breaks heterolytically, both electrons going to the far chlorine atom, which leaves as a chloride ion — a second curly arrow (2). • A carbocation intermediate is drawn, with the positive charge on one carbon and the chlorine on the other; accept the cyclic chloronium ion (1). • The chloride ion attacks the positively charged carbon, a third curly arrow from a lone pair to that carbon, giving the product (1).	**8**
(iv) Name of product	**1,2-dichloroethane**	**2**

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.