

PLUMI PRACTICE PACK

A Level Chemistry A

OCR-style practice pack (H432)

Mark scheme | Total 370 marks

Q	Section	Level	Topic	Specification	Marks
1	A	Easy	Magnesium: isotopes, electrons and reactions	2.1.1(b), 2.1.1(d), 2.2.1(d), 3.1.2(b), 2.1.3(e), 3.1.1(c), 3.1.2(c)	10
2	A	Medium	Hess's law: hydrating anhydrous copper(II) sulfate	3.2.1(d), 3.2.1(e), 3.2.1(g), 1.1.3(d), 1.1.4(d)	11
3	A	Medium	Equilibrium in the gas phase: N_2O_4 and NO_2	5.1.2(a), 5.1.2(d), 5.1.2(e), 5.1.2(g), 2.1.3(f), 3.2.3(b)	12
4	A	Medium	Group 2: hydrated barium chloride and barium hydroxide	2.1.3(d), 2.1.3(i), 3.1.2(b), 3.1.4(a), 5.1.3(e), 5.1.3(f), 1.1.4(c)	11
5	A	Hard	Rates: the iodination of propanone	5.1.1(a), 5.1.1(b), 5.1.1(c), 5.1.1(d), 5.1.1(h), 5.1.1(i)	14
6	A	Hard	Transition elements: cobalt complexes	5.3.1(a), 5.3.1(c), 5.3.1(e), 5.3.1(f), 5.3.1(h), 5.3.1(i), 3.2.3(b), 5.2.2(d), 5.2.2(e)	15
7	A	Hard	Electrode potentials: the oxidation states of vanadium	2.1.5(a), 5.2.3(c), 5.2.3(f), 5.2.3(h), 5.2.3(i), 5.2.3(j), 5.3.1(i)	12
8	A	Super hard	Lattice enthalpy, entropy and solubility: KCl and LiF	5.2.1(a), 5.2.1(b), 5.2.1(c), 5.2.1(d), 5.2.1(e), 5.2.2(c), 5.2.2(e)	14
9	A	Super hard	Rates practical: decomposition of benzenediazonium ions	5.1.1(a), 5.1.1(e), 5.1.1(f), 5.1.1(h), 5.1.1(k), 2.1.3(e), 1.1.1(a)	16
10	A	Super hard	Acids and buffers: identifying a weak acid from its titration curve	5.1.3(a), 5.1.3(c), 5.1.3(g), 5.1.3(j), 5.1.3(k), 5.1.3(l), 5.1.3(n), 2.1.4(e)	16
11	B	Easy	Alkenes: isomers of C_4H_8	4.1.1(a), 4.1.3(d), 4.1.3(f), 4.1.3(h), 4.1.3(i), 4.1.3(j), 2.1.3(e)	9
12	B	Medium	Alcohols: oxidising butan-1-ol	4.2.1(a), 4.2.1(c), 4.2.3(a), 4.2.4(c), 2.1.3(h), 2.2.2(k), 2.2.2(l)	11
13	B	Medium	Haloalkanes: rates of hydrolysis and ozone depletion	4.2.2(a), 4.2.2(b), 4.2.2(c), 4.2.2(d), 4.2.2(e), 4.1.1(i)	11
14	B	Medium	Aromatic chemistry: nitrating methyl benzoate	6.1.1(d), 6.1.1(e), 6.1.1(k), 6.2.5(a), 2.1.3(h)	11
15	B	Hard	Carbonyl compounds: identifying isomers and nucleophilic addition	6.1.2(b), 6.1.2(d), 6.1.2(e), 6.2.4(b), 6.2.4(c), 6.2.2(c), 6.3.2(a), 4.2.1(d), 4.1.3(c), 4.1.3(d)	15
16	B	Hard	Amino acids and chromatography: hydrolysing aspartame	6.2.2(a), 6.2.2(d), 6.2.3(a), 6.2.3(b), 6.3.1(a), 6.1.3(d), 1.1.4(c)	14
17	B	Hard	Synthesis: making paracetamol from phenol	6.1.1(h), 6.1.1(i), 6.1.1(j), 6.2.1(b), 6.1.3(f), 2.1.3(h), 2.1.3(j), 6.3.1(c)	14
18	B	Super hard	Combined techniques: identifying an ester	2.1.3(c), 4.2.4(c), 4.2.4(d), 4.2.4(f), 4.2.4(g), 6.3.2(a), 6.3.2(b), 6.3.2(e)	14
19	B	Super hard	Organic synthesis: planning a route to an amide	6.2.4(a), 6.2.4(b), 6.2.4(c), 6.2.1(b), 6.1.3(e), 6.1.3(f), 6.2.5(c), 6.3.2(c), 6.3.2(d)	12
20	B	Super hard	Polyesters: analysing a copolymer used for dissolving stitches	6.2.3(a), 6.2.3(b), 6.2.3(c), 6.1.3(d), 6.3.2(b), 2.1.4(e)	12
21	C	Easy	Practical skills: the concentration of ethanoic acid in vinegar	2.1.4(d), 2.1.4(e), 1.1.3(c), 1.1.4(d), 2.1.3(e)	9
22	C	Medium	Halogens and redox titrations: the strength of bleach	3.1.3(e), 3.1.3(f), 2.1.5(d), 5.2.3(d), 5.2.3(e), 2.1.3(e)	10
23	C	Medium	Bonding and intermolecular forces	2.2.2(g), 2.2.2(h), 2.2.2(i), 2.2.2(j), 2.2.2(k), 2.2.2(l)	12
24	C	Medium	Gases and energetics: identifying a volatile hydrocarbon	2.1.3(c), 2.1.3(f), 3.2.1(f), 4.1.1(e), 6.3.2(c)	11
25	C	Hard	Equilibrium and titration: forming ethyl ethanoate	3.2.3(f), 5.1.2(b), 5.1.2(c), 6.1.3(c), 2.1.4(e)	11
26	C	Hard	Transition metals and colorimetry: copper in brass	5.3.1(c), 5.3.1(h), 2.1.5(d), 2.1.5(f), 2.1.4(d), 1.1.3(d), 2.1.3(e)	12
27	C	Hard	Redox and energy: the direct ethanol fuel cell	5.2.3(b), 5.2.3(h), 5.2.3(k), 3.2.1(d), 2.1.3(e)	10
28	C	Super hard	Synthesis and analysis: the purity of aspirin	6.1.3(c), 6.1.3(d), 2.1.4(e), 2.1.3(h), 6.2.5(a), 6.2.5(b)	14
29	C	Super hard	Thermodynamics and equilibrium: manufacturing methanol	5.2.2(c), 5.2.2(e), 5.2.2(f), 5.1.2(a), 5.1.2(e), 5.1.2(g), 3.2.3(e)	14
30	C	Super hard	Transition metal analysis: a green iron complex salt	5.2.3(b), 5.2.3(d), 5.2.3(e), 5.3.1(c), 5.3.1(d), 5.3.1(f), 2.1.3(c), 2.1.3(d)	13
Total (A: 131, B: 123, C: 116)					370

OCR-style practice written by Plumi. Not produced or endorsed by OCR. Every number in this scheme has been independently re-checked by Plumi.



Annotations used in this mark scheme

Annotation	Meaning
✓	One mark for each marking point; the number of ticks in a part equals the marks for the part.
FIRST, CHECK THE ANSWER ON ANSWER LINE	For calculations: if the answer on the answer line is the one shown, award the marks stated. If not, check the working below for credit, including ECF.
6 (*)	Level of Response item, marked by levels (see below).
ECF	Error carried forward: credit for correct work that uses an incorrect earlier answer.
AW, ORA	Alternative wording; or reverse argument.
ALLOW / DO NOT ALLOW / IGNORE	Answers that are acceptable / not acceptable / irrelevant and not penalised.
/	Alternative and acceptable answers for the same marking point.
AO element	The assessment objective element each part targets (AO1 knowledge and understanding, AO2 application, AO3 analysis, interpretation and evaluation).

Subject-specific marking instructions

- **Calculations.** A correct final answer with no working scores full marks unless the question asks for working; an incorrect answer with no working scores 0. Where an answer is wrong, credit each correct step shown in the working.
- **Significant figures.** ALLOW numerical answers to 2 significant figures or more, up to the calculator value, unless the question asks for a stated number of significant figures or decimal places; pH values are given to 2 decimal places.
- **Error carried forward.** ECF is given for a correct method that uses an earlier incorrect value. ECF is not given where the method itself is wrong chemistry.
- **Equations.** Equations must be balanced; state symbols are required only where the question asks for them. Multiples and correct ionic equations are accepted unless stated.
- **Structures.** Any unambiguous structure (structural, displayed or skeletal) is accepted unless a type is asked for. Curly arrows must start from a bond, a lone pair or a negative charge.
- **Reagents and conditions.** ALLOW names of reagents if no formulae are given. IGNORE conditions unless they are stated incorrectly or the question asks for them.
- **Units.** Where the unit is printed on the answer line it need not be repeated; units of K_c , K_p and k are marked where the scheme shows a separate mark.

Level of Response items (*)

Read the whole answer. Decide the level from the science content against the level descriptors, then award the higher mark in the level if the communication statement for that level is met, otherwise the lower mark. The indicative scientific points are not a checklist; credit any valid chemistry. Level 0 (0 marks): no response, or no response worthy of credit.



SECTION A: PERIODIC TABLE, ELEMENTS AND PHYSICAL CHEMISTRY

Question 1 Physical · Easy · Magnesium: isotopes, electrons and reactions

Question	Answer	Marks	AO element	Guidance
1(a)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 24.32 award 2 marks -----	2	2.2 × 2	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$\frac{(24 \times 78.99) + (25 \times 10.00) + (26 \times 11.01)}{100} \checkmark$			Percentages read from Fig. 1.1
	24.32 ✓			Two decimal places required, as asked. 24.3 alone scores 1 mark
1(b)	protons 12, neutrons 13, electrons 10 ✓	1	2.2	All three needed
1(c)	1s ² 2s ² 2p ⁶ 3s ² ✓	1	1.1	ALLOW subscripts or numbers on the line. DO NOT ALLOW [Ne] 3s ² (full configuration asked)
1(d)	Mg(s) + H ₂ O(g) → MgO(s) + H ₂ (g) ✓	1	2.6	State symbols required. DO NOT ALLOW H ₂ O(l) for steam. DO NOT ALLOW Mg(OH) ₂ as a product
1(e)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 480 cm³ award 2 marks -----	2	2.2 × 2	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$n(\text{Mg}) = 0.486/24.3 = 0.0200 \text{ mol}$, so $n(\text{H}_2) = 0.0200 \text{ mol}$ ✓			Mg + 2HCl → MgCl ₂ + H ₂ : 1 : 1
	volume = 0.0200 × 24 000 = 480 cm ³ ✓			0.480 (dm ³ on a cm ³ answer line) scores 1 mark
1(f)	Calcium atoms have more shells, so the outer electron is further from the nucleus (larger atomic radius) ✓	3	1.1 × 3	ALLOW the outer electron is in a higher energy level / 4s rather than 3s
	More shielding by inner-shell electrons ✓			IGNORE 'more electron repulsion'
	Weaker nuclear attraction on the outer electron (so less energy is needed to remove it) ✓			ALLOW 'the greater nuclear charge is outweighed by the extra shielding and distance'. DO NOT ALLOW 'less nuclear charge'
	Total	10		

Marked by hand here. On iPad, Plumi marks questions like this one for you: tryplumi.app

Notes

(f) Common error: candidates refer to 'more shells' without linking distance or shielding to the attraction on the outermost electron; the third mark needs the attraction.



Question 1 notes continued

(a) The mean is weighted by abundance; a simple average of 24, 25 and 26 (25.00) shows a common misunderstanding.

Question 2 Physical · Medium · Hess's law: hydrating anhydrous copper(II) sulfate

Question	Answer	Marks	AO element	Guidance
2(a)	Water cannot be added in exactly the right amount / the solid would dissolve in the water rather than just hydrate / the reaction is too slow or incomplete to give a measurable temperature change ✓	1	2.1	DO NOT ALLOW 'it is difficult to measure' with no reason
2(b)(i)	$\Delta T = 7.8\text{ }^{\circ}\text{C}$ ✓	1	2.2	Both lines extrapolated to 3.0 min: about $20.0\text{ }^{\circ}\text{C}$ and $27.8\text{ }^{\circ}\text{C}$. ALLOW 7.7 to $7.9\text{ }^{\circ}\text{C}$
2(b)(ii)	Heat is lost to the surroundings while the solid dissolves, so the highest recorded temperature is too low; extrapolation estimates the temperature for instant dissolving with no heat loss ✓	1	1.1	ALLOW 'compensates for heat loss (cooling)'. ALLOW 'dissolving is not instantaneous so some heat is lost to the surroundings'. IGNORE 'to remove anomalies'
2(c)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = -65.2 kJ mol^{-1} award 3 marks -----	3	2.2 × 3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$q = 50.0 \times 4.18 \times 7.8 = 1630\text{ J}$ ✓			ECF from (b)(i). ALLOW mass 53.99 g (water plus solid): gives -70.4 kJ mol^{-1} , award 3 marks. Mass of solid (3.99 g) in $mc\Delta T$: max 1 (for n)
	$n(\text{CuSO}_4) = 3.99/159.6 = 0.0250\text{ mol}$ ✓			
	$\Delta_{\text{sol}}H = -1.630/0.0250 = -65.2\text{ kJ mol}^{-1}$ ✓			– sign AND 3 SF required. +65.2 scores 2. ALLOW ECF from q
2(d)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = -76.9 kJ mol^{-1} award 3 marks -----	3	2.2 × 3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$q = 50.0 \times 4.18 \times 1.4 = 292.6\text{ J}$; $n(\text{CuSO}_4 \cdot 5\text{H}_2\text{O}) = 6.24/249.6 = 0.0250\text{ mol}$ ✓			
	$\Delta_{\text{sol}}H(\text{CuSO}_4 \cdot 5\text{H}_2\text{O}) = +0.2926/0.0250 = +11.7\text{ kJ mol}^{-1}$ ✓			Must be positive: the temperature falls
	$\Delta_f H = -65.2 - (+11.7) = -76.9\text{ kJ mol}^{-1}$ ✓			ECF from (c). ALLOW -77 (2 s.f. data). -53.5 kJ mol^{-1} (cycle reversed, $-65.2 + 11.7$) scores 2

Question 2 continued

Question	Answer	Marks	AO element	Guidance
2(e)(i)	$\pm 0.2/1.4 \times 100 = 14\% \checkmark$	1	2.2	ALLOW 14.3%. Two readings, so $\pm 0.2^\circ\text{C}$ in the difference. 7.1% scores 0
2(e)(ii)	Use a larger mass of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (in the same volume of water) / use a smaller volume of water, so that the temperature change is larger $\checkmark$	1	3.4	DO NOT ALLOW 'use a more precise thermometer' (same apparatus); IGNORE 'repeat'
Total		11		

Notes

(c) Common errors: a missing negative sign and using the mass of the solid in $q = mc\Delta T$; the mass heated is the water.

(d) A cycle with both solutions forming the same aqueous Cu^{2+} and SO_4^{2-} makes the direction of each arrow clear: $\Delta_r H = \Delta_{\text{sol}} H(\text{anhydrous}) - \Delta_{\text{sol}} H(\text{hydrated})$.

Question 3 Physical · Medium · Equilibrium in the gas phase: N_2O_4 and NO_2

Question	Answer	Marks	AO element	Guidance
3(a)	$K_p = \frac{p(\text{NO}_2)^2}{p(\text{N}_2\text{O}_4)} \checkmark$	1	1.1	DO NOT ALLOW square brackets
3(b)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 71.2 kPa award 4 marks -----	4	2.2 × 4	IF there is an alternative answer, check for any ECF credit possible using the working below.
	Equilibrium amounts: $\text{N}_2\text{O}_4 = 0.200 - 0.060 = 0.140 \text{ mol}$; total = 0.260 mol $\checkmark$			Moles of N_2O_4 that react = half the moles of NO_2 formed
	$p(\text{NO}_2) = 0.120/0.260 \times 180 = 83.08 \text{ kPa}$; $p(\text{N}_2\text{O}_4) = 0.140/0.260 \times 180 = 96.92 \text{ kPa} \checkmark$			ALLOW mole fractions 0.462 and 0.538
	$K_p = 83.08^2/96.92 = 71.2 \checkmark$			ALLOW 71.1 to 71.3 (71.3 from pressures rounded to 3 s.f.). 0.080 mol of N_2O_4 (not halved) gives 162: scores 3 marks by ECF
	units: kPa $\checkmark$			Independent mark; ECF from an incorrect expression in (a). ALLOW $7.12 \times 10^4 \text{ Pa}$ if all pressures are in Pa. DO NOT ALLOW K_p with no units
3(c)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 3.84 dm³ award 2 marks -----	2	2.2 × 2	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$V = \frac{nRT}{p} = \frac{0.260 \times 8.314 \times 320}{180 \times 10^3} \checkmark$			Total amount of gas, and pressure in Pa

Question 3 continued

Question	Answer	Marks	AO element	Guidance
	$= 3.84 \times 10^{-3} \text{ m}^3 = 3.84 \text{ dm}^3 \checkmark$			ALLOW 3.8 dm^3 . 2.96 dm^3 (0.200 mol of gas used) scores 1
3(d)(i)	Amount of NO_2 decreases $\checkmark$	2	1.1 $\times 2$	
	Equilibrium shifts to the left, towards the side with fewer gas molecules (1 mol of gas, not 2) $\checkmark$			ALLOW 'to oppose the increase in pressure'
3(d)(ii)	No change: K_p depends only on temperature $\checkmark$	1	1.1	
3(e)	The forward reaction is endothermic, so the equilibrium shifts to the right (to oppose the rise in temperature), forming more brown $\text{NO}_2 \checkmark$	2	1.1 $\times 2$	
	K_p increases $\checkmark$			
	Total	12		

Notes

(b) Common error: taking the equilibrium amount of N_2O_4 as $0.200 - 0.120$; the stoichiometry halves the amount that dissociates.

(c) Common error: using $p = 180$ (kPa not converted to Pa) gives 3.84 m^3 , which is 3840 dm^3 .

Question 4 Physical · Medium · Group 2: hydrated barium chloride and barium hydroxide

Question	Answer	Marks	AO element	Guidance
4(a)	To make sure that all the water of crystallisation has been removed: heat to constant mass $\checkmark$	1	1.1	ALLOW 'until the mass stops changing'
4(b)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 2 award 3 marks -----	3	2.2 $\times 3$	IF there is an alternative answer, check for any ECF credit possible using the working below.
	mass of $\text{BaCl}_2 = 20.318 - 18.235 = 2.083 \text{ g}$; mass of water = $20.678 - 20.318 = 0.360 \text{ g} \checkmark$			Masses from the final (constant) reading
	$n(\text{BaCl}_2) = 2.083/208.3 = 0.0100 \text{ mol}$; $n(\text{H}_2\text{O}) = 0.360/18.0 = 0.0200 \text{ mol} \checkmark$			
	$x = 0.0200/0.0100 = 2 \checkmark$			$x = 2$ (a whole number). ALLOW 1.99 to 2.01 if shown unrounded ($x = 1.99$ from the 20.319 g reading) for 3 marks
4(c)	$x = (0.297/18.0) \div (2.146/208.3) = 1.60 \checkmark$	2	1.1 $\times 2$	ALLOW 1.6
	Not all the water had been removed, so the mass of water is too small (and the mass of BaCl_2 too large) $\checkmark$			
4(d)(i)	$\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) \checkmark$	1	2.6	State symbols required



Question 4 continued

Question	Answer	Marks	AO element	Guidance
4(d)(ii)	To remove carbonate ions, which would also give a white precipitate (BaCO_3) with Ba^{2+} ✓	1	1.1	ALLOW 'carbonate reacts with the acid to give CO_2 '
4(e)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 12.30 award 3 marks -----	3	2.2 × 3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$n(\text{Ba}) = 0.137/137.3 = 9.98 \times 10^{-4} \text{ mol}$, and $\text{Ba} + 2\text{H}_2\text{O} \rightarrow \text{Ba}(\text{OH})_2 + \text{H}_2$ ✓			
	$[\text{OH}^-] = 2 \times 9.98 \times 10^{-4}/0.1000 = 0.01996 \text{ mol dm}^{-3}$ ✓			Two OH^- per $\text{Ba}(\text{OH})_2$
	$[\text{H}^+] = K_w/[\text{OH}^-] = 5.01 \times 10^{-13} \text{ mol dm}^{-3}$, pH = 12.30 ✓			ALLOW 12.3. 12.00 (OH^- not doubled) scores 2
	Total	11		

Notes

- (e) Forgetting that each $\text{Ba}(\text{OH})_2$ provides two hydroxide ions is a common error with Group 2 hydroxides.
- (c) Reporting the effect on x without the reason scores one mark; the reason is the incomplete removal of water.

Question 5 Physical · Hard · Rates: the iodination of propanone

Question	Answer	Marks	AO element	Guidance
5(a)	So that their concentrations stay (effectively) constant: only the iodine concentration changes, so its effect on the rate is measured ✓	1	1.1	ALLOW 'they are in large excess'
5(b)(i)	Zero order ✓	2	2.1 × 2	
	The graph is a straight line: the rate (gradient) stays constant as $[\text{I}_2]$ falls ✓			ALLOW 'constant gradient'
5(b)(ii)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $2.24 \times 10^{-6} \text{ mol dm}^{-3} \text{ s}^{-1}$ award 2 marks -----	2	2.2 × 2	IF there is an alternative answer, check for any ECF credit possible using the working below.
	Gradient of the best-fit line, e.g. through (0, 2.00) and (800, 0.21): $1.79 \times 10^{-3} / 800$ ✓			Any two well-separated points on a best-fit line
	rate = $2.24 \times 10^{-6} \text{ mol dm}^{-3} \text{ s}^{-1}$ ✓			ALLOW 2.1 to 2.4×10^{-6} . IGNORE a negative sign. DO NOT ALLOW 2.24×10^{-3} (axis factor omitted)
5(c)(i)	Experiments 1 and 2: $[\text{CH}_3\text{COCH}_3]$ doubles, rate doubles, so first order in propanone ✓	3	2.1 × 3	ECF from (b)(ii)
	Experiments 2 and 3: $[\text{I}_2]$ and $[\text{H}^+]$ both double and rate doubles; iodine is zero order (Fig. 5.1), so first order in H^+ ✓			Must use the zero order from (b)(i)

Question 5 continued

Question	Answer	Marks	AO element	Guidance
	rate = $k[\text{CH}_3\text{COCH}_3][\text{H}^+]$ ✓			ALLOW $[\text{I}_2]^0$ included
5(c)(ii)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $2.80 \times 10^{-5} \text{ dm}^3 \text{ mol}^{-1} \text{ s}^{-1}$ award 2 marks -----	2	2.2 × 2	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$k = \frac{4.48 \times 10^{-6}}{0.800 \times 0.200} = 2.80 \times 10^{-5}$ ✓			ECF from (c)(i). ALLOW any experiment
	units: $\text{dm}^3 \text{ mol}^{-1} \text{ s}^{-1}$ ✓			ALLOW $\text{mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$; ECF for the rate equation in (c)(i)
5(d)	One propanone molecule and one H^+ ion are involved in (or before) the rate-determining step ✓	2	2.1 × 2	
	Iodine is not involved in the rate-determining step: it reacts in a (fast) step after it ✓			ALLOW 'the mechanism has more than one step'
5(e)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 670 s award 2 marks -----	2	2.2 × 2	IF there is an alternative answer, check for any ECF credit possible using the working below.
	Zero order: rate unchanged at $2.24 \times 10^{-6} \text{ mol dm}^{-3} \text{ s}^{-1}$; time = $1.50 \times 10^{-3} / 2.24 \times 10^{-6}$ ✓			ECF from (b)(ii)
	670 s ✓			ALLOW 625 to 715 s by ECF from (b)(ii). 446 s (half-life read from Fig. 5.1 taken as constant) scores 0
	Total	14		

Notes

What makes this hard: The graph is a straight line, and you have to read that as zero order in iodine. Table 5.1 changes $[\text{I}_2]$ and $[\text{H}^+]$ at the same time, so you can only find the order for H^+ once you know iodine is zero order. In (e), the half-life you can read off the graph does not stay the same for a zero-order reaction.

(c)(i) Experiments 2 and 3 change two concentrations together. Only the zero order deduced from Fig. 5.1 lets the order in H^+ be found; candidates who ignore the graph cannot separate the two.

(e) A constant half-life belongs to a first-order reaction. For zero order, $t_{1/2} = [\text{I}_2]_0 / 2k'$ and so increases with the starting concentration.

Question 6 Physical · Hard · Transition elements: cobalt complexes

Question	Answer	Marks	AO element	Guidance
6(a)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$ ✓	1	1.1	ALLOW $[\text{Ar}] 3d^7$. DO NOT ALLOW $4s^2 3d^5$
6(b)(i)	$[\text{Co}(\text{H}_2\text{O})_6]^{2+}$: octahedral, 90° ✓	2	1.1 × 2	
	$[\text{CoCl}_4]^{2-}$: tetrahedral, 109.5° ✓			ALLOW 109°
6(b)(ii)	ΔH is positive (endothermic) ✓	2	2.1 × 2	

Question 6 continued

Question	Answer	Marks	AO element	Guidance
	An increase in temperature shifts the equilibrium in the endothermic direction, to the right, forming more blue $[\text{CoCl}_4]^{2-}$ ✓			
6(b)(iii)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 333 K award 2 marks -----	3	2.2 × 3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	ΔS is positive: 5 particles (ions) form 7 particles ✓			ALLOW 'more moles of products'
	Feasible when $\Delta G < 0$; at the limit $\Delta G = 0$, so $T = \Delta H/\Delta S = 50/0.150$ ✓			$\Delta H = +50 \text{ kJ mol}^{-1}$ from (b) (ii). Units consistent (kJ and kJ K^{-1})
	$T = 333 \text{ K}$ ✓			ALLOW 333.3 K. 0.333 K (J and kJ mixed) scores 1
6(c)(i)	X: $n(\text{X}) = 0.500/250.4 = 2.00 \times 10^{-3} \text{ mol}$; $n(\text{AgCl}) = 0.573/143.4 = 4.00 \times 10^{-3} \text{ mol}$ ✓	4	2.1 × 4	$M(\text{X}) = 250.4 \text{ g mol}^{-1}$; $M(\text{AgCl}) = 143.4 \text{ g mol}^{-1}$
	2 free Cl^- per formula unit, so one Cl^- and five NH_3 are ligands: $[\text{Co}(\text{NH}_3)_5\text{Cl}]^{2+}$ ✓			ALLOW the compound written as $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$
	Y: $n(\text{Y}) = 0.500/233.4 = 2.14 \times 10^{-3} \text{ mol}$; $n(\text{AgCl}) = 0.307/143.4 = 2.14 \times 10^{-3} \text{ mol}$ ✓			$M(\text{Y}) = 233.4 \text{ g mol}^{-1}$
	1 free Cl^- per formula unit, so two Cl^- and four NH_3 are ligands: $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$ ✓			ALLOW the compound written as $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$
6(c)(ii)	Two octahedral 3D diagrams of $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$ (wedges and dashes), each with four NH_3 and two Cl ligands bonded to Co ✓	3	2.5 × 3	Bonds to the N of NH_3 . IGNORE the overall charge. ECF from (c)(i)
	One with the Cl ligands at 90° labelled <i>cis</i> ; one with the Cl ligands at 180° labelled <i>trans</i> ✓			Labels <i>cis</i> and <i>trans</i> required (OCR uses cis-trans for complexes)
	$[\text{Co}(\text{NH}_3)_5\text{Cl}]^{2+}$ has only one Cl ligand: every position for it is equivalent, so there is only one arrangement ✓			ALLOW 'all five NH_3 are identical, so no different spatial arrangements are possible'
	Total	15		

Notes

What makes this hard: Nothing tells you which chlorides are ligands: you have to work it out from how much silver chloride each compound gives. You then have to see that only one of the two complexes can have stereoisomers.

(c)(i) The tempting formulae give different masses of AgCl from 0.500 g of Y: $[\text{Co}(\text{NH}_3)_4\text{Cl}]\text{Cl}_2$ would give 0.614 g and $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$ none. This is the evidence Werner used.

(b)(iii) The calculation agrees with (b)(ii): an endothermic process with positive ΔS becomes feasible only above $\Delta H/\Delta S$.

Question 7 Physical · Hard · Electrode potentials: the oxidation states of vanadium

Question	Answer	Marks	AO element	Guidance
7(a)	VO_2^+ : +5 and VO^{2+} : +4 ✓	1	2.2	Both needed. ALLOW 5+ and 4+
7(b)	Both vanadium species are ions in solution: platinum is an inert conductor that allows electron transfer ✓	1	1.1	ALLOW 'no solid form of the redox pair'
7(c)	$E_{\text{cell}} = 1.00 - (-0.76) = 1.76 \text{ V}$ ✓	2	3.1 × 2	
	$\text{Zn} + 2\text{VO}_2^+ + 4\text{H}^+ \rightarrow \text{Zn}^{2+} + 2\text{VO}^{2+} + 2\text{H}_2\text{O}$ ✓			IGNORE state symbols. ALLOW multiples
7(d)	Zinc (−0.76 V) is more negative than all three vanadium systems, so it reduces VO_2^+ to VO^{2+} (blue), then V^{3+} (green), then V^{2+} (violet) ✓	3	3.1 × 3	ALLOW E_{cell} values 1.76, 1.10 and 0.50 V
	Tin (−0.14 V) reduces VO_2^+ to VO^{2+} ($E_{\text{cell}} = +1.14 \text{ V}$) and VO^{2+} to V^{3+} ($E_{\text{cell}} = +0.48 \text{ V}$) ✓			
	Tin cannot reduce V^{3+} to V^{2+} : $E_{\text{cell}} = -0.12 \text{ V}$, so the solution stays green (V^{3+}) ✓			
7(e)	VO^{2+} (blue) ✓	2	2.1 × 2	
	Fe^{3+} (+0.77 V) oxidises V^{2+} and V^{3+} (−0.26 and +0.34 V are less positive) but cannot oxidise VO^{2+} to VO_2^+ : +1.00 V is more positive than +0.77 V ✓			ALLOW $E_{\text{cell}} = -0.23 \text{ V}$ for the last step
7(f)(i)	$1.00 - (-0.26) = 1.26 \text{ V}$ ✓	1	2.2	
7(f)(ii)	The concentrations are not 1 mol dm^{-3} (non-standard conditions) ✓	2	2.1 × 2	ALLOW temperature not 298 K
	High $[\text{VO}_2^+]$ and $[\text{H}^+]$ make the positive electrode potential more positive, and high $[\text{V}^{2+}]$ makes the negative electrode potential more negative, so E_{cell} is larger ✓			ALLOW either electrode argued correctly
	Total	12		

Notes

What makes this hard: Zinc and tin are both reducing agents, but they stop at different vanadium ions. You have to test each step one at a time instead of comparing just the first one. In (f), the voltage changes because the concentrations are not 1 mol dm^{-3} .

(d) and (e): each step must be tested separately; a single comparison of the reducing agent with the first vanadium couple cannot predict where the reduction stops.

(f)(ii) Standard electrode potentials apply only at 1 mol dm^{-3} ; they predict feasibility but say nothing about the voltage under the conditions in a working cell.

Question 8 Physical · Super hard · Lattice enthalpy, entropy and solubility: KCl and LiF

Question	Answer	Marks	AO element	Guidance
8(a)	Upper blank line: $K^+(g) + Cl(g) + e^-$ ✓	2	1.1 × 2	DO NOT ALLOW the electron omitted. State symbols and charges required
	Lower blank line: $K^+(g) + Cl^-(g)$ ✓			State symbols and charges required. DO NOT ALLOW KCl(g)
8(b)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = +18 kJ mol⁻¹ award 3 marks -----	3	2.2 × 3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	Lattice enthalpy = $-437 - (89 + 419 + 122 - 349) = -718 \text{ kJ mol}^{-1}$ ✓			
	$\Delta_{\text{sol}}H = -(\text{lattice enthalpy}) + \Delta_{\text{hyd}}H(K^+) + \Delta_{\text{hyd}}H(Cl^-) = 718 + (-322) + (-378)$ ✓			ECF from an incorrect lattice enthalpy
	$\Delta_{\text{sol}}H = +18 \text{ kJ mol}^{-1}$ ✓			Sign required. -1418 (lattice enthalpy not reversed) scores 1 mark
8(c)	$\Delta_{\text{sol}}S = (102.5 + 56.5) - 82.6 = +76.4 \text{ J K}^{-1} \text{ mol}^{-1}$ ✓	4	2.1 × 4	
	Feasible when $\Delta G = \Delta H - T\Delta S < 0$; at the limit $\Delta G = 0$, so $T = \Delta H/\Delta S = 18/0.0764$ ✓			Units consistent (kJ and kJ K ⁻¹). ECF from (b)
	$T = 236 \text{ K}$ ✓			ALLOW 235.5 to 236 K. 0.236 K (J and kJ mixed) scores 2
	Feasible at all temperatures above 236 K (-37 °C), so at every temperature at which water is liquid ✓			Direction of the inequality required
8(d)	$\Delta_{\text{sol}}H(\text{LiF}) = 1036 - 519 - 512 = +5 \text{ kJ mol}^{-1}$ ✓	5	3.3 × 5	
	$\Delta_{\text{sol}}S(\text{LiF}) = (13.4 + (-13.8)) - 35.7 = -36.1 \text{ J K}^{-1} \text{ mol}^{-1}$ ✓			
	$\Delta G(\text{LiF}) = +5 - 298 \times (-0.0361) = +15.8 \text{ kJ mol}^{-1}$ ✓			ALLOW +16. ECF from ΔS
	ΔH alone does not decide solubility, because $\Delta G = \Delta H - T\Delta S$. KCl: $T\Delta S = 298 \times 0.0764 = +22.8 \text{ kJ mol}^{-1}$ outweighs $\Delta H = +18 \text{ kJ mol}^{-1}$, so $\Delta G = -4.8 \text{ kJ mol}^{-1}$ (negative). LiF: ΔS is negative, so $-T\Delta S = +10.8 \text{ kJ mol}^{-1}$ adds to $\Delta H = +5 \text{ kJ mol}^{-1}$, so $\Delta G = +15.8 \text{ kJ mol}^{-1}$ (positive). So the claim is wrong ✓			1 mark for the conclusion that uses both salts. ECF from (b) and (c)
	Li^+ and F^- are small ions with a high charge density: they attract and order many water molecules around them, so the solution is less disordered than the separate solid and water ✓			ALLOW 'strong hydration orders the water molecules'
	Total	14		

Question 8 notes continued

Notes

What makes this hard: No route is given for the enthalpy change of solution: you have to combine the Born-Haber cycle with the hydration enthalpies yourself. You then need ΔG for both salts, keeping J and kJ straight. The claim looks right if you only look at ΔH ; it fails once you include entropy.

(c) Mixing J and kJ is the classic error: ΔS must be divided by 1000 before it is combined with ΔH in kJ mol^{-1} .

(d) LiF does dissolve slightly; a positive ΔG for 1 mol dm^{-3} solution means it is sparingly soluble, not insoluble. KCl (about 4.6 mol dm^{-3} at room temperature) is far more soluble, the opposite of the claim.

Question 9 Physical · Super hard · Rates practical: decomposition of benzenediazonium ions

Question	Answer	Marks	AO element	Guidance
9(a)*	Level 3 (5 or 6 marks) A clear method that would give reliable results, including temperature control and how V_{∞} is obtained, and a clear explanation of how the results show the order, using half-lives or another valid method. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 or 4 marks) A method with some detail of how results are collected and some processing; or a clear method only; or a clear explanation of the processing only. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 or 2 marks) Some relevant method or some relevant processing. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	1.2 × 2 3.4 × 4	Indicative scientific points may include: Method - Measure 50.0 cm^3 of the diazonium solution (pipette or burette) into the conical flask; keep it cold (ice) until the start - Place the flask in a thermostatically controlled water bath at $50.0 \text{ }^{\circ}\text{C}$; check the temperature of the bath with a thermometer - Connect the gas syringe with a gas-tight bung; check the syringe is at zero and moves freely - Start the stopclock when the flask goes into the bath; read the syringe volume at regular intervals (for example every 2 minutes) - Continue until the volume stops changing, or calculate V_{∞} from the amount of diazonium ion ($24.0 \text{ dm}^3 \text{ mol}^{-1}$ at RTP) - Repeat the experiment and take means; safety: diazonium salts are unstable, wear eye protection Processing - Volume of N_2 still to be released ($V_{\infty} - V$) is proportional to $[\text{C}_6\text{H}_5\text{N}_2^+]$ - Plot V (or $V_{\infty} - V$) against time and measure successive half-lives - Constant half-life shows first order; $k = \ln 2/t_{1/2}$ - Or: draw tangents to find rates at several times and plot rate against ($V_{\infty} - V$); a straight line through the origin shows first order



Question	Answer	Marks	AO element	Guidance
9(b)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $1.44 \times 10^{-3} \text{ s}^{-1}$ award 4 marks -----	5	2.2 × 5	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$V_{\infty} = 0.0800 \times 0.0500 \times 24\,000 = 96.0 \text{ cm}^3 \checkmark$			The hidden step: V_{∞} is not reached on Fig. 9.2
	Half-life: time for V to reach $48.0 \text{ cm}^3 = 480 \text{ s} \checkmark$			ALLOW 470 to 490 s
	Second half-life (48.0 to 72.0 cm^3 , 480 s to 960 s) is also 480 s : constant half-life, so first order $\checkmark$			Two half-lives must be measured
	$k = \ln 2/480 = 1.44 \times 10^{-3} \checkmark$			ECF from the half-life
	units: $\text{s}^{-1} \checkmark$			ALLOW 1.41 to $1.47 \times 10^{-3} \text{ s}^{-1}$ from the allowed half-lives. ALLOW alternative methods: rate from tangents at two times and $(V_{\infty} - V)$ read from the curve, $\text{rate}/(V_{\infty} - V)$ constant so first order, $k = \text{rate}/(V_{\infty} - V)$; or $\ln(V_{\infty} - V)$ against t is a straight line, $k = -\text{gradient}$. ALLOW k 1.39 to $1.51 \times 10^{-3} \text{ s}^{-1}$ for the $\ln(V_{\infty} - V)$ route; ALLOW 1.30 to $1.58 \times 10^{-3} \text{ s}^{-1}$ for the tangent route
9(c)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 110 kJ mol^{-1} award 3 marks -----	3	2.2 × 3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	k at $40.0 \text{ }^{\circ}\text{C} = \ln 2/1780 = 3.89 \times 10^{-4} \text{ s}^{-1} \checkmark$			Ratio of half-lives equals the inverse ratio of k
	$\ln \frac{k_{323}}{k_{313}} = \frac{E_a}{R} \left(\frac{1}{313} - \frac{1}{323} \right)$, so $E_a = \frac{8.314 \times \ln(1780/480)}{9.89 \times 10^{-5}} \checkmark$			ALLOW two simultaneous $\ln k = -E_a/RT + \ln A$ equations
	$E_a = 110 \text{ kJ mol}^{-1} \checkmark$			ALLOW 109 to 111 kJ mol^{-1} . 1.10×10^5 given as the answer in kJ mol^{-1} scores 2 marks
9(d)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $67 \text{ }^{\circ}\text{C}$ award 2 marks -----	2	2.2 × 2	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$k = \ln 2/60 = 0.0116 \text{ s}^{-1}$; $\frac{1}{T} = \frac{1}{323} - \frac{8.314 \ln(480/60)}{1.10 \times 10^5} \checkmark$			ECF from (b) and (c)
	$T = 340 \text{ K}$, so $67 \text{ }^{\circ}\text{C} \checkmark$			ALLOW 66 to $68 \text{ }^{\circ}\text{C}$
	Total	16		

Question 9 notes continued

Notes

What makes this hard: The graph stops before the reaction finishes, so you cannot read the final volume off it: you have to calculate it from the amount of benzenediazonium ions. Half of that final volume tells you the half-life. You then need the Arrhenius equation twice: once for E_a , then to find a temperature.

(b) Common error: taking half the last plotted volume (39.4 cm^3 at 1200 s) as the half-way point, which gives a 'half-life' of about 360 s. The reaction is far from complete at 1200 s, so V_∞ must come from the amount of diazonium ion.

(c) and (d) A two-point Arrhenius calculation follows from writing $\ln k = -E_a/RT + \ln A$ at each temperature and subtracting; $\ln A$ cancels.

Question 10 Physical · Super hard · Acids and buffers: identifying a weak acid from its titration curve

Question	Answer	Marks	AO element	Guidance
10(a)	Equivalence volume from Fig. 10.1 = 30.0 cm^3 ✓	5	2.1 × 5	ALLOW 29.8 to 30.2 cm^3
	$n(\text{NaOH}) = 0.0500 \times 30.0/1000 = 1.50 \times 10^{-3} \text{ mol} = n(\text{A})$ in 25.0 cm^3 (one sharp end point, so A reacts 1 : 1 and is monobasic) ✓			
	$n(\text{A})$ in $250.0 \text{ cm}^3 = 1.50 \times 10^{-2} \text{ mol}$; $M = 1.35/0.0150 = 90.0 \text{ g mol}^{-1}$ ✓			Scaling by 10 required: 900 g mol^{-1} (not scaled) loses this mark only
	pH at half-neutralisation (15.0 cm^3) = $\text{p}K_a = 3.86$ ✓			ALLOW 3.82 to 3.90 read from the curve
	$M = 90.0$ ($\text{C}_3\text{H}_6\text{O}_3$) rules out hydroxyethanoic acid ($M = 76.0$); $\text{p}K_a$ 3.86 rules out the other two isomers: A is 2-hydroxypropanoic acid ✓			Both eliminations needed
10(b)	A buffer forms: the solution contains both HA and its conjugate base A^- in significant amounts ✓	2	1.1 × 2	
	Added OH^- reacts with HA ($\text{OH}^- + \text{HA} \rightarrow \text{A}^- + \text{H}_2\text{O}$), so $[\text{HA}]/[\text{A}^-]$ and $[\text{H}^+]$ change only a little ✓			ALLOW: $\text{HA} \rightleftharpoons \text{H}^+ + \text{A}^-$; added OH^- removes H^+ , the equilibrium shifts right and $[\text{H}^+]$ is restored (pH changes only a little). DO NOT ALLOW an explanation that cites an equilibrium that does not exist (e.g. for a strong acid)
10(c)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 2.54 award 2 marks -----	3	2.2 × 3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$[\text{HA}] = 0.0150/0.250 = 0.0600 \text{ mol dm}^{-3}$; $K_a = 10^{-3.86} = 1.38 \times 10^{-4} \text{ mol dm}^{-3}$ ✓			ECF from (a)
	$[\text{H}^+] = \sqrt{(1.38 \times 10^{-4} \times 0.0600)} = 2.88 \times 10^{-3} \text{ mol dm}^{-3}$; pH = 2.54 ✓			ALLOW 2.54 to 2.55 (2.55 from the exact quadratic); agrees with Fig. 10.1
	Assumption: $[\text{HA}]$ at equilibrium ≈ 0.0600 (dissociation is small) / $[\text{H}^+] = [\text{A}^-]$ (H^+ from water negligible) ✓			



Question 10 continued

Question	Answer	Marks	AO element	Guidance
10(d)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 3.56 award 3 marks -----	3	2.2 ×3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$n(\text{OH}^-)$ added = $0.0500 \times 10.0/1000 = 5.00 \times 10^{-4}$ mol; $n(\text{HA})$ left = $1.50 \times 10^{-3} - 5.00 \times 10^{-4} = 1.00 \times 10^{-3}$ mol; $n(\text{A}^-) = 5.00 \times 10^{-4}$ mol ✓			ECF from (a)
	$[\text{H}^+] = K_a \times [\text{HA}]/[\text{A}^-] = 1.38 \times 10^{-4} \times 2.00 = 2.76 \times 10^{-4}$ mol dm ⁻³ ✓			ALLOW $\text{pH} = \text{p}K_a + \log(0.500)$; volume cancels
	$\text{pH} = 3.56$ ✓			ALLOW 3.55 to 3.57; agrees with Fig. 10.1. 4.16 (ratio inverted) scores 2
10(e)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 24.4 cm³ award 3 marks -----	3	2.2 ×3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$\text{pH} = \text{p}K_a + \log([\text{A}^-]/[\text{HA}])$, so $[\text{A}^-]/[\text{HA}] = 10^{0.64} = 4.37$ ✓			ALLOW $[\text{H}^+] = K_a[\text{HA}]/[\text{A}^-]$ with $[\text{H}^+] = 3.16 \times 10^{-5}$
	fraction of HA neutralised = $4.37/5.37 = 0.814$ ✓			
	volume = $0.814 \times 30.0 = 24.4$ cm ³ ✓			ALLOW 24.3 to 24.5 cm ³ . 5.6 cm ³ (ratio inverted) scores 1 mark
	Total	16		

Notes

What makes this hard: You are only told to identify A. You have to realise you need both the molar mass (from the end point) and the $\text{p}K_a$ (from half-neutralisation): three of the acids have the same molar mass. Remember that the 25.0 cm³ you titrated is one tenth of the solution. In (e), you have to spot that a partly neutralised weak acid is a buffer.

(a) Molar mass alone leaves three isomers; $\text{p}K_a$ alone cannot separate 3.83 from 3.86 within the reading accuracy of the curve. Only the two together identify A, which is why both are needed for the final mark.

(c) The weak-acid approximation is good here (2.54 against 2.55 from the exact solution) because only about 5% of the acid dissociates.

SECTION B: SYNTHESIS AND ANALYTICAL TECHNIQUES

Question 11 Synthesis · Easy · Alkenes: isomers of C₄H₈

Question	Answer	Marks	AO element	Guidance
11(a)	2-methylpropene ✓	1	1.1	ALLOW methylpropene
11(b)	There is restricted rotation about the C=C double bond (π -bond) ✓	2	1.1 × 2	
	In B each carbon of the C=C bond has two different groups (H and CH ₃); in A one carbon of the C=C bond has two H atoms ✓			
11(c)(i)	Electrophilic addition ✓	1	1.1	
11(c)(ii)	(CH ₃) ₃ CBr, 2-bromo-2-methylpropane ✓	2	2.5 × 2	Any unambiguous structure
	It forms from the more stable tertiary carbocation, (CH ₃) ₃ C ⁺ (more alkyl groups donating electrons) ✓			ALLOW Markownikoff's rule with reference to carbocation stability. DO NOT ALLOW 'H adds to the carbon with more H' alone
11(d)	-CH ₂ -C(CH ₃) ₂ - with continuation bonds at both ends ✓	1	2.5	Brackets and <i>n</i> not required; continuation bonds required
11(e)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 2.40 dm³ award 2 marks -----	2	2.2 × 2	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$n(\text{C}_4\text{H}_8) = 1.40/56.0 = 0.0250 \text{ mol}$; $n(\text{CO}_2) = 4 \times 0.0250 = 0.100 \text{ mol}$ ✓			$\text{C}_4\text{H}_8 + 6\text{O}_2 \rightarrow 4\text{CO}_2 + 4\text{H}_2\text{O}$
	volume = $0.100 \times 24.0 = 2.40 \text{ dm}^3$ ✓			ALLOW 2.4 dm ³
	Total	9		

Marked by hand here. On iPad, Plumi marks questions like this one for you: tryplumi.app

Notes

(c)(ii) The explanation must refer to the stability of the carbocation intermediate; quoting Markownikoff's rule without it gains the structure mark only.

Question 12 Synthesis · Medium · Alcohols: oxidising butan-1-ol

Question	Answer	Marks	AO element	Guidance
12(a)	Heating under reflux ✓	2	1.1 × 2	DO NOT ALLOW distillation
	Volatile reactants and products condense and return to the flask, so the butanal formed first stays in contact with the oxidising agent and is oxidised to the carboxylic acid ✓			ALLOW 'volatile substances are not lost'
12(b)	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + 2[\text{O}] \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} + \text{H}_2\text{O}$ ✓	1	2.6	ALLOW molecular formulae if structure is clear



Question 12 continued

Question	Answer	Marks	AO element	Guidance
12(c)	Orange to green ✓	1	1.1	
12(d)	C=O absorption in the range 1630 to 1820 cm ⁻¹ (about 1725 cm ⁻¹) ✓	2	3.1 × 2	
	No broad O–H absorption at 2500 to 3300 cm ⁻¹ or 3200 to 3600 cm ⁻¹ , so the distillate is butanal (an aldehyde), CH ₃ CH ₂ CH ₂ CHO ✓			Both the absence of O–H and the identity needed
12(e)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 60.0 % award 2 marks -----	2	2.2 × 2	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$n(\text{butan-1-ol}) = 7.40/74.0 = 0.100 \text{ mol}$; $n(\text{butanal}) = 4.32/72.0 = 0.0600 \text{ mol}$ ✓			
	percentage yield = 60.0% ✓			ALLOW 60%. ECF for a different product named in (d)
12(f)	Butan-1-ol forms hydrogen bonds between molecules (O–H group); butanal cannot (no H bonded to O) ✓	2	1.1 × 2	
	Butanal has (permanent dipole-dipole and London forces) weaker intermolecular forces, so less energy is needed to overcome them ✓			ALLOW the reverse argument
12(g)	It is a tertiary alcohol: there is no hydrogen atom on the carbon bonded to the OH group ✓	1	1.1	
	Total	11		

Notes

(d) Credit is given only when the absence of the O–H absorption is used; the C=O absorption alone cannot tell an aldehyde from a carboxylic acid.

Question 13 Synthesis · Medium · Haloalkanes: rates of hydrolysis and ozone depletion

Question	Answer	Marks	AO element	Guidance
13(a)	Haloalkanes are insoluble in water: ethanol is a solvent in which the haloalkane and the aqueous silver nitrate mix ✓	1	1.1	ALLOW 'common solvent'
13(b)	Yellow ✓	1	1.1	DO NOT ALLOW cream



Question 13 continued

Question	Answer	Marks	AO element	Guidance
13(c)	Dipole on C–Br ($C^{\delta+}$, $Br^{\delta-}$) and curly arrow from a lone pair on O of OH^- to the $C^{\delta+}$ atom ✓	3	1.2 × 3	Curly arrow must start from a lone pair or the negative charge on the O of OH^- . DO NOT ALLOW a curly arrow starting from the H of OH^- or from the O atom symbol rather than a lone pair or the negative charge. Curly arrows may be straight or snake-like but not half-headed
	Curly arrow from the C–Br bond to Br ✓			
	Products: $CH_3CH_2CH_2CH_2OH$ and Br^- ✓			ALLOW a transition state shown
13(d)	Rate: iodo > bromo > chloro (iodo fastest) ✓	3	3.1 × 3	From Table 13.1
	C–I has the lowest bond enthalpy, so it is broken most easily (C–Cl the highest) ✓			
	C–Cl is the most polar bond (greatest $\delta+$ on C) and C–I the least, so polarity would predict the opposite order: bond enthalpy, not polarity, decides the rate ✓			ALLOW 'C–I is non-polar (equal electronegativities)'
13(e)(i)	$Cl\cdot + O_3 \rightarrow ClO\cdot + O_2$ ✓	2	2.6 × 2	ALLOW dots anywhere on the radical
	$ClO\cdot + O \rightarrow Cl\cdot + O_2$ ✓			ALLOW $ClO\cdot + O_3 \rightarrow Cl\cdot + 2O_2$
13(e)(ii)	The C–F bond is stronger (higher bond enthalpy) than the C–Cl bond, so UV radiation breaks C–Cl ✓	1	2.1	
	Total	11		

Notes

(d) Common error: the polarity argument. C–I is the least polar bond but reacts fastest, so the data rule it out.

(c) Marks are often lost for curly arrows that start from the O atom rather than from a lone pair, or that point to the wrong carbon.

Question 14 Synthesis · Medium · Aromatic chemistry: nitrating methyl benzoate

Question	Answer	Marks	AO element	Guidance
14(a)	$\text{HNO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{NO}_2^+ + \text{HSO}_4^- + \text{H}_2\text{O} \checkmark$	1	2.6	ALLOW $\text{HNO}_3 + 2\text{H}_2\text{SO}_4 \rightarrow \text{NO}_2^+ + 2\text{HSO}_4^- + \text{H}_3\text{O}^+$. ALLOW $\text{HNO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{NO}_3^+ + \text{HSO}_4^-$ then $\text{H}_2\text{NO}_3^+ \rightarrow \text{H}_2\text{O} + \text{NO}_2^+$
14(b)	Curly arrow from inside the delocalised ring (π -system) to NO_2^+ $\checkmark$	3	1.2 $\times$ 3	ALLOW to any part of the NO_2^+ ion; ALLOW NO_2 or NO_2^+ . Ring may be benzene with the ester group shown at position 1
	Intermediate: horseshoe covering approximately four of the six sides of the ring (five carbons), gap towards the sp^3 carbon carrying H and NO_2 at position 3 to the ester group, + inside the horseshoe $\checkmark$			
	Curly arrow from the C–H bond back into the ring, forming the product and H^+ $\checkmark$			ALLOW HSO_4^- removing H^+ ; ALLOW $\text{H}^+ + \text{HSO}_4^- \rightarrow \text{H}_2\text{SO}_4$ shown. Arrows may be straight or snake-like but not half-headed or double-headed
14(c)	To prevent further nitration (formation of dinitro products) / to control the exothermic reaction $\checkmark$	1	2.1	
14(d)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 67.4 % award 2 marks -----	2	2.2 $\times$ 2	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$n(\text{methyl benzoate}) = 2.72/136.0 = 0.0200 \text{ mol}$; $n(\text{product}) = 2.44/181.0 = 0.01348 \text{ mol} \checkmark$			$M(\text{C}_8\text{H}_8\text{O}_2) = 136.0$; $M(\text{C}_8\text{H}_7\text{NO}_4) = 181.0$
	percentage yield = 67.4% $\checkmark$			ALLOW 67%
14(e)(i)	Dissolve in the minimum volume of hot ethanol $\checkmark$	3	1.2 $\times$ 3	
	Allow to cool (then in ice) so that crystals form; soluble impurities stay in solution $\checkmark$			
	Filter (under reduced pressure) AND leave to dry $\checkmark$			ALLOW dry in a desiccator or in an oven below the melting point. IGNORE washing with cold solvent. IGNORE hot filtration. DO NOT ALLOW use of a drying agent (e.g. MgSO_4)



Question 14 continued

Question	Answer	Marks	AO element	Guidance
14(e)(ii)	The product is (almost) pure: impurities would lower the melting point and widen the range ✓	1	2.1	ALLOW 'contains a small amount of impurity: the range is 2 °C and starts below the data-book value', with the explanation that impurities lower the melting point and widen the range
	Total	11		

Notes

(b) The ester group is electron-withdrawing and directs substitution to the 3-position; candidates may show the attack at C3 without explaining the directing effect.

Question 15 Synthesis · Hard · Carbonyl compounds: identifying isomers and nucleophilic addition

Question	Answer	Marks	AO element	Guidance
15(a)	Both contain a carbonyl group (C=O): they react with 2,4-DNP ✓	4	2.1 × 4	
	K is an aldehyde (silver mirror); L is a ketone ✓			
	K is 2-methylpropanal, (CH ₃) ₂ CHCHO: three carbon environments (the two CH ₃ groups are equivalent); butanal would give four peaks ✓			Structure or name, with the reason
	L is butanone, CH ₃ COCH ₂ CH ₃ ✓			The only ketone C ₄ H ₈ O
15(b)	Dipole on C=O (C ^{δ+} , O ^{δ-}) and curly arrow from the lone pair (or negative charge) on the C of CN ⁻ to the C ^{δ+} ✓	4	1.2 × 4	Arrow must start from the carbon of CN ⁻
	Curly arrow from the C=O π-bond to O ✓			
	Intermediate: CH ₃ C(O ⁻)(CN)CH ₂ CH ₃ ✓			
	Curly arrow from O ⁻ to H ⁺ (or to H of H ₂ O / HCN), giving CH ₃ C(OH)(CN)CH ₂ CH ₃ ✓			
15(c)	The C=O group (and the carbon atom attacked) is planar ✓	2	1.1 × 2	
	CN ⁻ attacks from above and below with equal probability, so equal amounts of the two optical isomers (enantiomers) form ✓			ALLOW '50 : 50 mixture'
15(d)	CH ₃ C(OH)(CN)CH ₂ CH ₃ + 2H ₂ O + HCl → CH ₃ C(OH)(COOH)CH ₂ CH ₃ + NH ₄ Cl ✓	2	2.6 × 2	N correct
	Equation balanced, including 2H ₂ O and NH ₄ Cl (or NH ₄ ⁺) ✓			ALLOW H ⁺ in place of HCl, with NH ₄ ⁺ as a product
15(e)	CH ₂ =C(CH ₂ CH ₃)COOH (loss of H from the CH ₃ on the carbon bearing OH) ✓	3	2.5 × 3	ECF from N in (d)



Question 15 continued

Question	Answer	Marks	AO element	Guidance
	$\text{CH}_3\text{CH}=\text{C}(\text{CH}_3)\text{COOH}$ drawn as two stereoisomers (loss of H from the CH_2) ✓			
	Z: higher-priority groups (COOH and CH_3) on the same side; E: on opposite sides (CIP: on C3, $\text{CH}_3 > \text{H}$; on C2, $\text{COOH} > \text{CH}_3$) ✓			Labels must match the drawn isomers. DO NOT ALLOW 'same plane'
	Total	15		

Notes

What makes this hard: Butanal and 2-methylpropanal both pass the tests; only the number of ^{13}C peaks separates them. In (e), the OH can be lost in two directions, and one of the alkenes has E and Z forms that you name by CIP priorities.

(a) Butanal and 2-methylpropanal both give a silver mirror; the ^{13}C NMR peak count is the only evidence that separates them.

(b) Common error: a curly arrow starting from the nitrogen of CN^- ; the new bond is C–C.

Question 16 Synthesis · Hard · Amino acids and chromatography: hydrolysing aspartame

Question	Answer	Marks	AO element	Guidance
16(a)	Two asterisks: on the CH carbon bonded to NH_2 (aspartic acid part) and on the CH carbon bonded to the NH of the amide and to $\text{CH}_2\text{C}_6\text{H}_5$ (phenylalanine part) ✓	1	2.5	Both, and no others
16(b)	CH_3OH ✓	3	2.5×3	
	$\text{HOOCCH}_2\text{CH}(\text{NH}_3^+)\text{COOH}$ ✓			$-\text{NH}_3^+$ required (excess acid); ALLOW $-\text{NH}_3^+\text{Cl}^-$
	$\text{C}_6\text{H}_5\text{CH}_2\text{CH}(\text{NH}_3^+)\text{COOH}$ ✓			If both amino acids are drawn with $-\text{NH}_2$, award 1 of these 2 marks
16(c)	Measured from the baseline: solvent front 8.0 cm; spots in M at 1.92 cm and 4.65 cm; $R_f = 0.24$ and 0.58 ✓	3	3.1×3	ALLOW ± 0.1 cm on each distance (R_f 0.23 to 0.25 and 0.57 to 0.60)
	Lower spot level with reference A: aspartic acid ✓			Not level with G
	Upper spot level with reference P: phenylalanine ✓			
16(d)	R_f values depend on the conditions (solvent, temperature, plate), so data-book values may not apply to this plate ✓	2	3.1×2	
	A and G differ by only about 1.6 mm (R_f 0.24 and 0.26), about the reading uncertainty of each distance, so only a side-by-side comparison on the same plate tells them apart ✓			ALLOW 'the R_f values are too close to distinguish by measurement alone'
16(e)	CH_3OH ✓	3	2.5×3	



Question 16 continued

Question	Answer	Marks	AO element	Guidance
	$^-OOCCH_2CH(NH_2)COO^-$ (with $2Na^+$) ✓			Both carboxylate groups and a free $-NH_2$ required
	$C_6H_5CH_2CH(NH_2)COO^-$ (with Na^+) ✓			If both amino acids are drawn as acids ($COOH$), award 1 of these 2 marks
16(f)	$-NH(CH_2)_5CO-$ with continuation bonds ✓	2	2.5 × 2	Amide link shown; brackets and <i>n</i> not required
	Condensation polymerisation ✓			
	Total	14		

Notes

What makes this hard: Acid and alkaline hydrolysis give the same amino acids in different forms, so you have to think about which groups are protonated. On the chromatogram, aspartic acid and glycine are less than 2 mm apart, so only the reference lanes can tell them apart.

(b) and (e) Common error: drawing the neutral amino acids. In excess acid the amine groups are protonated; in excess alkali the carboxylic acid groups are deprotonated and the amine groups are free.

(d) A reading error of 1 mm changes R_f by about 0.0125, so 0.24 and 0.26 cannot be separated by measurement; the reference lanes settle it.

Question 17 Synthesis · Hard · Synthesis: making paracetamol from phenol

Question	Answer	Marks	AO element	Guidance
17(a)	Step 1: dilute nitric acid at room temperature ✓	3	1.1 × 3	DO NOT ALLOW concentrated HNO_3 with concentrated H_2SO_4
	Step 2: tin and concentrated hydrochloric acid ✓			
	then (an excess of) $NaOH(aq)$ ✓			ALLOW 'heat under reflux' with Sn/HCl
17(b)	A lone pair on the oxygen of OH is delocalised into the π -system of the ring ✓	2	1.1 × 2	Must state that the lone pair is on O
	The electron density of the ring is higher than in benzene, so the ring polarises / attracts the electrophile (NO_2^+) more strongly ✓			Comparison with benzene needed. No concentrated H_2SO_4 catalyst is needed (not required for the mark)
17(c)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 27.3 g award 3 marks -----	3	2.2 × 3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	overall yield = $0.38 \times 0.80 \times 0.75 = 0.228$ ✓			
	$n(\text{paracetamol}) = 10.0/151.0 = 0.0662 \text{ mol};$ $n(\text{phenol}) = 0.0662/0.228 = 0.290 \text{ mol}$ ✓			$M(C_8H_9NO_2) = 151.0$



Question 17 continued

Question	Answer	Marks	AO element	Guidance
	mass of phenol = $0.290 \times 94.0 = 27.3 \text{ g}$ ✓			ALLOW 27.2 to 27.4 g. 6.23 g (all three yields ignored) scores 1 mark. 1.42 g (n(paracetamol) multiplied by 0.228 instead of divided) scores 1 mark
17(d)	Ethanoyl chloride: $\text{C}_6\text{H}_7\text{NO} + \text{CH}_3\text{COCl} \rightarrow \text{C}_8\text{H}_9\text{NO}_2 + \text{HCl}$; atom economy = $151.0/187.5 \times 100 = 80.5\%$ ✓	3	3.3 × 3	
	Ethanoic anhydride: $\text{C}_6\text{H}_7\text{NO} + (\text{CH}_3\text{CO})_2\text{O} \rightarrow \text{C}_8\text{H}_9\text{NO}_2 + \text{CH}_3\text{COOH}$; atom economy = $151.0/211.0 \times 100 = 71.6\%$ ✓			
	Ethanoic anhydride is used despite its lower atom economy: it is less reactive (safer, easier to control), cheaper, and gives no corrosive HCl; the ethanoic acid by-product can be used ✓			Any one valid reason
17(e)	$\text{HOC}_6\text{H}_4\text{NHCOCH}_3 + \text{NaOH} \rightarrow \text{NaOC}_6\text{H}_4\text{NHCOCH}_3 + \text{H}_2\text{O}$ ✓	3	2.6 × 3	ALLOW ionic equation, or the phenoxide drawn. DO NOT ALLOW hydrolysis of the amide (cold, dilute NaOH)
	With $\text{Na}_2\text{CO}_3(\text{aq})$, paracetamol gives no effervescence (no CO_2): phenols are weaker acids than carbonic acid, so no CO_2 is released ✓			
	A carboxylic acid would react with Na_2CO_3 and give effervescence (CO_2) ✓			ALLOW the reverse argument
	Total	14		

Notes

What makes this hard: Yields over three steps have to be worked backwards to find a starting mass. The atom economy favours one reagent, but the practical reasons point to the other. In (e), phenols and carboxylic acids both react with NaOH; only sodium carbonate tells them apart.

(c) The yields are applied backwards: dividing by the overall fraction. Multiplying by it gives an impossible answer smaller than the theoretical amount.

(d) The atom economy comparison favours ethanoyl chloride; the evaluation mark is for recognising why industry chooses otherwise.

Question 18 Synthesis · Super hard · Combined techniques: identifying an ester

Question	Answer	Marks	AO element	Guidance
18(a)	$\text{C} : \text{H} : \text{O} = 62.1/12.0 : 10.3/1.0 : 27.6/16.0 = 5.175 : 10.3 : 1.725$ ✓	3	2.1 × 3	O by difference (27.6%)
	Empirical formula $\text{C}_3\text{H}_6\text{O}$ ✓			Ratio 3 : 5.97 : 1

Question 18 continued

Question	Answer	Marks	AO element	Guidance
	Molecular ion at $m/z = 116$, so molecular formula $C_6H_{12}O_2$ ✓			$M(C_3H_6O) = 58.0$; $116/58.0 = 2$
18(b)	C=O absorption in 1630 to 1820 cm^{-1} and C–O absorption in 1000 to 1300 cm^{-1} (about 1735 and 1180 cm^{-1}): an ester ✓	2	3.1 × 2	
	No broad O–H absorption at 2500 to 3300 cm^{-1} , so not a carboxylic acid ✓			
18(c)	Quartet (2H) and triplet (3H): an ethyl group, CH_3CH_2- ✓	4	3.1 × 4	n + 1 rule applied to both
	Septet (1H) and doublet (6H): a 1-methylethyl group, $(CH_3)_2CH-$ ✓			
	Quartet at $\delta\ 4.1$ (H–C–O): the CH_2 is bonded to O; septet at $\delta\ 2.5$ (H–C–C=O): the CH is next to C=O ✓			Chemical shifts used for both
	P is ethyl 2-methylpropanoate, $(CH_3)_2CHCOOCH_2CH_3$ ✓			Structure required for this mark
18(d)	The splitting and areas show only the two alkyl groups and the ester link; they do not show which alkyl group is on the O and which is on the C=O ✓	4	2.1 × 4	
	1-Methylethyl propanoate (propan-2-yl propanoate), $CH_3CH_2COOCH(CH_3)_2$ ✓			Name and structure
	In this isomer the septet (CH bonded to O) would be in the H–C–O region (3.0 to 4.3 on the Data Sheet; about 5.0 in practice) and the quartet (CH_2 next to C=O) at 2.0 to 3.0 ; in Fig. 18.3 the quartet is at 4.1 and the septet at 2.5 ✓			Chemical shift argument for both peaks
	The fragment at $m/z = 71$ is $(CH_3)_2CHCO^+$; the isomer would give $CH_3CH_2CO^+$ at $m/z = 57$, which is absent ✓			Positive charge required on the fragment
18(e)	5 ✓	1	3.1	
Total		14		

Notes

What makes this hard: The splitting and peak areas fit two different esters equally well. You have to use the chemical shifts and the mass spectrum fragment to decide which group is joined to the oxygen.

(c) The splitting pattern and relative peak areas fit two esters equally well; only the chemical shifts decide which group is next to O. This is why (d) is needed.

(a) Candidates often stop at the empirical formula; the molecular ion at 116 is needed for $C_6H_{12}O_2$.

Question 19 Synthesis · Super hard · Organic synthesis: planning a route to an amide

Question	Answer	Marks	AO element	Guidance
19(a)*	Level 3 (5 or 6 marks) A complete and correct route to Q: both the four-carbon acyl part and the three-carbon amine part are made from 1-bromopropane, with correct reagents and conditions and correct intermediates for every step, and the types of reaction named. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 or 4 marks) A route that makes one part correctly from 1-bromopropane with reagents, conditions and intermediates, and attempts to combine the parts; or a complete route with some errors or omissions in reagents, conditions or types of reaction. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 or 2 marks) Some correct steps, reagents or intermediates, with limited detail. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	1.2 ×2 3.2 ×4	Indicative scientific points may include: Four-carbon acyl part 1-bromopropane + KCN (or NaCN) in ethanol, heat under reflux: $\text{CH}_3\text{CH}_2\text{CH}_2\text{CN}$, butanenitrile; nucleophilic substitution - Hydrolysis: heat under reflux with dilute HCl (or H_2SO_4): $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$, butanoic acid - Butanoic acid + SOCl_2: $\text{CH}_3\text{CH}_2\text{CH}_2\text{COCl}$, butanoyl chloride ($\text{SO}_2$ and HCl also form) Three-carbon amine part 1-bromopropane + an excess of ammonia in ethanol, heated (in a sealed tube): $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$, propylamine; nucleophilic substitution - Excess ammonia reduces further substitution to secondary and tertiary amines Final step - Butanoyl chloride + propylamine at room temperature: Q + HCl (or propylammonium chloride with a second mole of amine); a condensation (addition-elimination) reaction - Note: reducing butanenitrile (H_2/Ni) gives butylamine, which has the wrong chain length for the amine part Marking notes - Haloalkane to nitrile: KCN or NaCN in ethanol. DO NOT ALLOW HCN, CN^-/H^+ or aqueous KCN - Haloalkane to amine: excess NH_3 in ethanol. ALLOW 'ethanolic ammonia' - IGNORE conditions (sealed tube, heat) unless stated incorrectly. ALLOW names of reagents if no formulae are given
19(b)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 12.9 g award 3 marks -----	3	2.2 ×3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$n(1\text{-bromopropane}) = 24.6/122.9 = 0.200 \text{ mol } \checkmark$			$M(\text{C}_3\text{H}_7\text{Br}) = 122.9$
	Two moles of 1-bromopropane are needed per mole of Q (one for each part), so $n(\text{Q}) = 0.100 \text{ mol } \checkmark$			The hidden step; ECF from the route in (a)



Question 19 continued

Question	Answer	Marks	AO element	Guidance
	mass of Q = $0.100 \times 129.0 = 12.9 \text{ g}$ ✓			$M(\text{C}_7\text{H}_{15}\text{NO}) = 129.0$. 25.8 g (1 : 1 ratio) scores 2 marks by ECF
19(c)	7 peaks ✓	3	3.1 ×3	ALLOW 6 if the N–H peak is stated to be absent
	CH ₂ bonded to C=O: triplet (next to a CH ₂ with 2 H) ✓			
	The N–H peak disappears: the H on N exchanges with deuterium, and D does not give a peak ✓			
	Total	12		

Notes

What makes this hard: No intermediates are named. You have to see that 1-bromopropane must provide both halves of the amide: the four-carbon part needs a nitrile step to add a carbon, and the three-carbon part comes straight from the haloalkane. That also means two moles of 1-bromopropane for every mole of product in (b).

(a) Many plans make butylamine by reducing butanenitrile and so produce *N*-butylbutanamide; the amine part must be made directly from 1-bromopropane to keep three carbon atoms.

(b) The 2 : 1 ratio follows only from a plan in which 1-bromopropane provides both parts; the scheme credits a consistent ratio from the candidate's own plan.

Question 20 Synthesis · Super hard · Polyesters: analysing a copolymer used for dissolving stitches

Question	Answer	Marks	AO element	Guidance
20(a)	$\text{HOCH}(\text{CH}_3)\text{COO}^- (\text{Na}^+)$ ✓	2	2.5 ×2	Carboxylate salts required (excess NaOH). DO NOT ALLOW an alkoxide ($-\text{O}^-$) on the alcohol group. ALLOW Na^+ shown or omitted
	$\text{HOCH}_2\text{COO}^- (\text{Na}^+)$ ✓			If both are drawn as acids, award 1 of the 2 marks
20(b)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 75 % award 5 marks -----	5	2.2 ×5	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$n(\text{HCl}) = 0.100 \times 26.00/1000 = 2.600 \times 10^{-3} \text{ mol} = n(\text{NaOH})$ left in 25.0 cm^3 ✓			
	NaOH left in $100.0 \text{ cm}^3 = 4 \times 2.600 \times 10^{-3} = 1.040 \times 10^{-2} \text{ mol}$ ✓			Scaling by 4 required
	NaOH used = $0.0250 - 0.0104 = 0.0146 \text{ mol} =$ moles of repeat units ✓			One OH^- per repeat unit (one ester link, or the COOH end, per unit)
	mean mass per repeat unit = $1.00/0.0146 = 68.5 \text{ g mol}^{-1}$; with $-\text{OCH}(\text{CH}_3)\text{CO}- = 72.0$ and $-\text{OCH}_2\text{CO}- = 58.0$: $72.0x + 58.0(1 - x) = 68.5$ ✓			Both repeat-unit masses needed

Question 20 continued

Question	Answer	Marks	AO element	Guidance
	$x = 0.75$, so 75% of the repeat units contain a methyl group ✓			ALLOW 74 to 76%
20(c)	Doublet (area 9) = CH_3 and quartet (area 3) = CH of the methyl-containing unit; singlet (area 2) = CH_2 of the other unit ✓	3	3.1×3	OH and COOH protons exchange with D_2O and are not seen
	Ratio = $9/3 : 2/2$ (or $3/1 : 2/2$) = $3 : 1$ ✓			Each area divided by the number of H it represents
	$3 : 1$ is 75% : 25%, which agrees with (b) ✓			ECF from (b)
20(d)	The ester links in Z are polar and are hydrolysed (by water, catalysed by enzymes or acid) in the body ✓	2	1.1×2	
	Poly(propene) has only non-polar C–C and C–H bonds, which are not attacked by water ✓			ALLOW 'poly(alkenes) are saturated and unreactive'
	Total	12		

Notes

What makes this hard: You have to see that each repeat unit uses exactly one hydroxide ion when the polymer is hydrolysed, so a back titration counts the repeat units. Only a quarter of the solution was titrated. In (c), each peak area has to be divided by the number of hydrogens it represents before you compare them.

(b) Two errors are common: forgetting that only a quarter of the solution was titrated, and assuming two OH^- per repeat unit. Each repeat unit contains one ester group (the last unit has a COOH end group instead), so one OH^- per unit.

(c) The NMR and titration methods are independent: agreement is good evidence that hydrolysis was complete.



SECTION C: UNIFIED CHEMISTRY

Question 21 Unified · Easy · Practical skills: the concentration of ethanoic acid in vinegar

Question	Answer	Marks	AO element	Guidance
21(a)	Final reading for titration 2: 46.85 ✓	2	1.1 × 2	Read at the bottom of the meniscus. ALLOW 46.80 to 46.90. DO NOT ALLOW a reading to 1 d.p.
	Titre for titration 2: 23.20 ✓			Titre ECF from the reading, to 2 d.p.
21(b)	$(23.15 + 23.20 + 23.15)/3 = 23.17 \text{ cm}^3$ ✓	1	3.1	ALLOW 23.16(7). DO NOT ALLOW a mean including the rough titre. ECF from (a)
21(c)	$\text{CH}_3\text{COOH} + \text{NaOH} \rightarrow \text{CH}_3\text{COONa} + \text{H}_2\text{O}$ ✓	1	2.6	ALLOW ionic equation
21(d)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $0.927 \text{ mol dm}^{-3}$ award 3 marks -----	3	3.1 × 3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$n(\text{NaOH}) = 0.100 \times 23.17/1000 = 2.317 \times 10^{-3} \text{ mol}$ $= n(\text{CH}_3\text{COOH}) \text{ in } 25.0 \text{ cm}^3$ ✓			ECF from (b)
	$[\text{CH}_3\text{COOH}] \text{ in diluted vinegar} = 2.317 \times 10^{-3}/0.0250 = 0.0927 \text{ mol dm}^{-3}$ ✓			
	original vinegar: $\times 10 = 0.927 \text{ mol dm}^{-3}$ ✓			ALLOW 0.93. 0.0927 (dilution ignored) scores 2
21(e)	$0.927 \times 60.0 = 55.6 \text{ g dm}^{-3}$ ✓	1	3.1	ECF from (d)
21(f)	$2 \times 0.05/23.20 \times 100 = 0.43\%$ ✓	1	3.1	Two readings. ALLOW 0.431%
Total		9		

Marked by hand here. On iPad, Plumi marks questions like this one for you: tryplumi.app

Notes(b) The rough titre is never included; concordant titres agree within 0.10 cm^3 .

(d) The factor of 10 for the dilution is the step most often missed.

Question 22 Unified · Medium · Halogens and redox titrations: the strength of bleach

Question	Answer	Marks	AO element	Guidance
22(a)	Cl in Cl_2 : 0; in NaCl: -1; in NaClO: +1 ✓	2	2.1 × 2	All three
	Chlorine is both reduced (0 to -1) and oxidised (0 to +1) in the same reaction ✓			
22(b)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 50.7 g dm^{-3} award 4 marks -----	4	3.1 × 4	IF there is an alternative answer, check for any ECF credit possible using the working below.



Question 22 continued

Question	Answer	Marks	AO element	Guidance
	$n(\text{S}_2\text{O}_3^{2-}) = 0.100 \times 13.60/1000 = 1.360 \times 10^{-3} \text{ mol}$ ✓			
	$n(\text{I}_2) = n(\text{ClO}^-) = 6.80 \times 10^{-4} \text{ mol in } 25.0 \text{ cm}^3$ ✓			$\text{ClO}^- : \text{I}_2 : \text{S}_2\text{O}_3^{2-} = 1 : 1 : 2$
	$n(\text{ClO}^-)$ in 10.0 cm^3 of bleach = $6.80 \times 10^{-3} \text{ mol}$; [NaClO] = $0.680 \text{ mol dm}^{-3}$ ✓			Scaling by 10, then by 100 for 1 dm^3
	concentration = $0.680 \times 74.5 = 50.7 \text{ g dm}^{-3}$ ✓			ALLOW 51 g dm^{-3} . 101 g dm^{-3} (1 : 2 not used) scores 3
22(c)(i)	Blue-black to colourless ✓	1	1.1	ALLOW blue to colourless
22(c)(ii)	At high iodine concentration the starch-iodine complex forms and does not release the iodine readily, giving an inaccurate (late) end point ✓	1	1.1	ALLOW 'the blue-black colour would hide the fading of the iodine colour'
22(d)	$\text{ClO}^- + \text{Cl}^- + 2\text{H}^+ \rightarrow \text{Cl}_2 + \text{H}_2\text{O}$ ✓	2	2.6 × 2	ALLOW full equation with NaClO and HCl
	Toxic chlorine gas is released ✓			
	Total	10		

Notes

(b) The two scale factors (portion of the diluted solution, then dilution of the bleach) are where most marks are lost; household bleach contains about 5% NaClO, so a value near 50 g dm^{-3} is a useful sense check.

Question 23 Unified · Medium · Bonding and intermolecular forces

Question	Answer	Marks	AO element	Guidance
23(a)	Propane: London (induced dipole-dipole) forces only ✓	4	1.1 × 4	
	Methoxymethane: permanent dipole-dipole forces (polar C–O bonds, bent molecule) as well as London forces ✓			
	Ethanol: hydrogen bonds between molecules (H bonded to O) ✓			
	Strength: hydrogen bonds > permanent dipole-dipole > London forces, so more energy is needed to overcome the intermolecular forces in ethanol, then methoxymethane, then propane ✓			Must refer to energy to overcome intermolecular forces. DO NOT ALLOW breaking covalent bonds
23(b)	Two ethanol molecules with $\text{O}^{\delta-}$ and $\text{H}^{\delta+}$ on the O–H bonds, and a lone pair on the O of one molecule ✓	2	2.5 × 2	
	Hydrogen bond drawn as a dashed line from that lone pair to the $\text{H}^{\delta+}$ of the other molecule, and labelled 'hydrogen bond' ✓			IGNORE the angle of the hydrogen bond. DO NOT ALLOW a hydrogen bond to an H on carbon
23(c)	NH_3 : 107° ✓	3	2.1 × 3	ALLOW 106 to 108°

Question 23 continued

Question	Answer	Marks	AO element	Guidance
	NH_4^+ : 109.5° ✓			ALLOW 109°
	NH_3 has one lone pair; lone pairs repel more than bonding pairs, so the bond angle is reduced. NH_4^+ has four bonding pairs and no lone pairs ✓			DO NOT ALLOW repulsion between atoms or bonds (electron pairs must be stated)
23(d)	The molecule is linear (symmetrical), so the two bond dipoles are equal and opposite and cancel ✓	1	1.1	
23(e)	Both form hydrogen bonds (one OH group each) ✓	2	1.1×2	
	Propan-1-ol has more electrons (a longer chain, larger surface contact), so stronger London forces: more energy is needed to overcome the intermolecular forces ✓			DO NOT ALLOW 'more hydrogen bonds'
	Total	12		

Notes

(a) Answers that say 'ethanol has stronger bonds' without naming intermolecular forces score at most 2; covalent bonds are not broken on boiling.

Question 24 Unified · Medium · Gases and energetics: identifying a volatile hydrocarbon

Question	Answer	Marks	AO element	Guidance
24(a)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 86.0 award 3 marks -----	3	3.1×3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$n = \frac{pV}{RT} = \frac{101 \times 10^3 \times 71.4 \times 10^{-6}}{8.314 \times 373}$ ✓			Pressure in Pa, volume in m^3 , temperature in K
	$n = 2.325 \times 10^{-3} \text{ mol}$ ✓			
	$M_r = 0.200 / 2.325 \times 10^{-3} = 86.0$ ✓			ALLOW 85.8 to 86.2
24(b)	$n(\text{C}) = 0.614 / 44.0 = 0.01395 \text{ mol}$; $n(\text{H}) = 2 \times 0.293 / 18.0 = 0.03256 \text{ mol}$ ✓	3	1.1×3	
	C : H = $1 : 2.33 = 3 : 7$, so the empirical formula is C_3H_7 ✓			
	$M(\text{C}_3\text{H}_7) = 43.0$; $86.0 / 43.0 = 2$, so C_6H_{14} ✓			ECF from (a)
24(c)(i)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $-3908 \text{ kJ mol}^{-1}$ award 2 marks -----	2	3.1×2	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$\text{C}_6\text{H}_{14} + 9\frac{1}{2}\text{O}_2 \rightarrow 6\text{CO}_2 + 7\text{H}_2\text{O}$: bonds broken = $5(347) + 14(413) + 9.5(498) = 12\,248 \text{ kJ}$; bonds formed = $12(805) + 14(464) = 16\,156 \text{ kJ}$ ✓			
	$\Delta_c H = 12\,248 - 16\,156 = -3908 \text{ kJ mol}^{-1}$ ✓			Sign required



Question 24 continued

Question	Answer	Marks	AO element	Guidance
24(c)(ii)	Average bond enthalpies are used, not the actual values for the bonds in hexane ✓	2	2.1 × 2	
	Bond enthalpies apply to gases: under standard conditions hexane and water are liquids, so energy changes of vaporisation and condensation are not included ✓			
24(d)	2,3-dimethylbutane skeletal formula ✓	1	2.5	Only 2 H environments: 12 H (CH ₃) and 2 H (CH)
	Total	11		

Notes

(a) Unit conversions decide this part: 71.4 cm³ is 71.4 × 10⁻⁶ m³, and 100 °C is 373 K.

Question 25 Unified · Hard · Equilibrium and titration: forming ethyl ethanoate

Question	Answer	Marks	AO element	Guidance
25(a)	$K_c = \frac{[\text{CH}_3\text{COOC}_2\text{H}_5][\text{H}_2\text{O}]}{[\text{CH}_3\text{COOH}][\text{C}_2\text{H}_5\text{OH}]}$ ✓	1	1.1	
25(b)	To slow the reaction (by cooling and dilution), so that the amounts do not change while the titration is carried out ✓	1	1.1	ALLOW 'to freeze the equilibrium'
25(c)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 4.00 award 5 marks -----	5	3.1 × 5	IF there is an alternative answer, check for any ECF credit possible using the working below.
	titre due to ethanoic acid = 24.15 – 3.60 = 20.55 cm ³ ✓			The hidden step: the catalyst is also titrated
	$n(\text{CH}_3\text{COOH})$ in 25.0 cm ³ = 0.500 × 20.55/1000 = 1.0275 × 10 ⁻² mol; in 250.0 cm ³ = 0.10275 mol ✓			
	$n(\text{ester}) = n(\text{H}_2\text{O}) = 0.250 - 0.10275 = 0.14725$ mol ✓			
	$n(\text{C}_2\text{H}_5\text{OH}) = 0.200 - 0.14725 = 0.05275$ mol ✓			
	$K_c = \frac{0.14725^2}{0.10275 \times 0.05275} = 4.00$ ✓			ALLOW 4.0. The whole titre taken as ethanoic acid gives 1.96: scores 4 marks (ECF)
25(d)	There are equal numbers of moles on both sides, so the volume cancels in the expression (K_c has no units) ✓	1	1.1	
25(e)	$\frac{x^2}{(0.250 - x)(0.400 - x)} = 4.00$, so $3x^2 - 2.6x + 0.4 = 0$ ✓	3	3.3 × 3	ECF from (c)

Question 25 continued

Question	Answer	Marks	AO element	Guidance
	$x = 0.200$ mol of ethyl ethanoate ✓			The other root (0.667) is impossible: more than the acid present
	0.200 mol is 1.36 times (not twice) 0.147 mol: the prediction is wrong; the extra ethanol increases the yield but cannot double it (at most 0.250 mol) ✓			
	Total	11		

Notes

What makes this hard: The sulfuric acid catalyst is still in the flask and reacts with the NaOH too, so you have to subtract its titre first. In (e), you have to solve the equilibrium again to test the claim.

(c) Common error: treating the whole titre as ethanoic acid; the sulfuric acid catalyst is still present and is neutralised too.

(e) The equilibrium amount is limited by the ethanoic acid (0.250 mol), so doubling the ethanol can never double the ester.

Question 26 Unified · Hard · Transition metals and colorimetry: copper in brass

Question	Answer	Marks	AO element	Guidance
26(a)	$\text{Cu} + 4\text{HNO}_3 \rightarrow \text{Cu}(\text{NO}_3)_2 + 2\text{NO}_2 + 2\text{H}_2\text{O}$ ✓	2	2.6 × 2	ALLOW ionic equation
	Nitrogen is reduced: +5 in HNO_3 to +4 in NO_2 ✓			Both oxidation numbers needed
26(b)	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}$ ✓	1	2.6	ALLOW ⇌
26(c)	Zn^{2+} ($3d^{10}$) and its ammonia complex are colourless: they do not absorb visible light ✓	1	1.1	ALLOW 'full d sub-shell'
26(d)	Orange is the complementary colour of the deep blue solution: it is the colour of light most strongly absorbed, giving the largest change in absorbance with concentration ✓	1	1.1	ALLOW 'the solution absorbs orange light'
26(e)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 59 % award 4 marks -----	4	3.1 × 4	IF there is an alternative answer, check for any ECF credit possible using the working below.
	From Fig. 26.1: concentration = $9.3 \times 10^{-3} \text{ mol dm}^{-3}$ ✓			ALLOW 9.2 to $9.5 \times 10^{-3} \text{ mol dm}^{-3}$
	$n(\text{Cu})$ in $50.0 \text{ cm}^3 = 9.3 \times 10^{-3} \times 0.0500 = 4.65 \times 10^{-4} \text{ mol}$ (= amount in 10.0 cm^3 of the brass solution) ✓			
	$n(\text{Cu})$ in $100.0 \text{ cm}^3 = 4.65 \times 10^{-3} \text{ mol}$; mass = $4.65 \times 10^{-3} \times 63.5 = 0.295 \text{ g}$ ✓			Scaling by 10
	percentage = $0.295/0.500 \times 100 = 59\%$ ✓			ALLOW 58 to 60%



Question 26 continued

Question	Answer	Marks	AO element	Guidance
26(f)	volume of copper(II) sulfate solution = $6.0 \times 10^{-3} \times 100.0/0.0500 = 12.0 \text{ cm}^3$ ✓	3	1.2 ×3	
	Measure 12.0 cm^3 with a burette (or graduated pipette) into a 100.0 cm^3 volumetric flask ✓			DO NOT ALLOW measuring cylinder
	Add an excess of aqueous ammonia, make up to the mark with distilled water (bottom of the meniscus on the line), stopper and invert to mix ✓			Excess ammonia and making up to the mark both needed
	Total	12		

Notes

What makes this hard: Two dilutions go in opposite directions: the measured solution is weaker than the brass solution, but it holds only a tenth of the copper. You also have to explain why the zinc does not affect the reading.

(e) The two dilutions undo in opposite senses: 10.0 cm^3 is diluted to 50.0 cm^3 (the measured solution is weaker), but it is one tenth of the 100.0 cm^3 that contains all the copper.

(d) A filter of the same colour as the solution would pass light the solution does not absorb, so the readings would hardly change with concentration.

Question 27 Unified · Hard · Redox and energy: the direct ethanol fuel cell

Question	Answer	Marks	AO element	Guidance
27(a)	$\text{CH}_3\text{CH}_2\text{OH} + 3\text{H}_2\text{O} \rightarrow 2\text{CO}_2 + 12\text{H}^+ + 12\text{e}^-$ ✓	2	2.1 ×2	Species correct: $\text{CH}_3\text{CH}_2\text{OH}$ and H_2O on the left; CO_2 , H^+ and e^- on the right
	Balanced, with 12 electrons ✓			ALLOW the reverse with $\rightleftharpoons$
27(b)	$E_{\text{cell}} = 1.23 - 0.08 = 1.15 \text{ V}$ ✓	2	1.1 ×2	
	$\text{CH}_3\text{CH}_2\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}$ ✓			ALLOW multiples
27(c)	$\text{CH}_3\text{CH}_2\text{OH} + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{COOH} + 4\text{H}^+ + 4\text{e}^-$ ✓	2	2.1 ×2	
	$4/12 \times 100 = 33\%$ ✓			ECF from the electron numbers
27(d)	Ethanol: $1367/46.0 = 29.7 \text{ kJ g}^{-1}$ ✓	4	3.3 ×4	
	Hydrogen: $286/2.0 = 143 \text{ kJ g}^{-1}$ ✓			
	Per dm^3 : ethanol $29.7 \times 789 = 2.34 \times 10^4 \text{ kJ dm}^{-3}$; hydrogen $286/24.0 = 11.9 \text{ kJ dm}^{-3}$ ✓			Both values
	The claim is true per gram (about 5 times) but false per dm^3 (ethanol about 2000 times more); hydrogen must be compressed or liquefied for storage ✓			Conclusion must use both comparisons
	Total	10		

Question 27 notes continued

Notes

What makes this hard: You have to build a half-equation for an organic fuel from scratch. In (d), whether hydrogen is the better fuel depends on whether you compare per gram or per dm^3 , so you need both calculations.

(a) Balancing organic half-equations: balance C, then O with H_2O , then H with H^+ , then charge with electrons.

(d) The comparison depends on whether mass or volume matters for the application; a single figure cannot settle 'better'.

Question 28 Unified · Super hard · Synthesis and analysis: the purity of aspirin

Question	Answer	Marks	AO element	Guidance
28(a)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 91.9 % award 5 marks -----	5	3.1 × 5	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$n(\text{HCl}) = 0.0500 \times 7.75/1000 = 3.875 \times 10^{-4} \text{ mol} = \text{NaOH left in } 25.0 \text{ cm}^3 \checkmark$			
	$\text{NaOH left in } 250.0 \text{ cm}^3 = 3.875 \times 10^{-3} \text{ mol}; \text{NaOH at the start} = 0.200 \times 0.0500 = 0.0100 \text{ mol} \checkmark$			
	$\text{NaOH reacted with aspirin} = 0.0100 - 0.003875 = 6.125 \times 10^{-3} \text{ mol} \checkmark$			
	$n(\text{aspirin}) = 6.125 \times 10^{-3}/2 = 3.0625 \times 10^{-3} \text{ mol}$ (ester hydrolysis and COOH neutralisation) $\checkmark$			The hidden step; 1 : 1 gives 184%, impossible
	$\text{mass} = 3.0625 \times 10^{-3} \times 180.0 = 0.5513 \text{ g}; \text{purity} = 0.5513/0.600 \times 100 = 91.9\% \checkmark$			ALLOW 91.8 to 92.0%
28(b)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 76.6 % award 4 marks -----	4	3.1 × 4	IF there is an alternative answer, check for any ECF credit possible using the working below.
	Let $a = \text{mol aspirin}$ and $s = \text{mol 2-hydroxybenzoic acid}$: $180.0a + 138.0s = 0.600 \checkmark$			Mass equation
	$2a + s = 6.125 \times 10^{-3}$ (the impurity uses one NaOH, at its COOH group) $\checkmark$			ECF from (a)
	solving: $a = 2.555 \times 10^{-3} \text{ mol}$, so mass of aspirin = 0.4598 g $\checkmark$			$s = 1.02 \times 10^{-3} \text{ mol}$ (0.140 g)
	true purity = $0.4598/0.600 \times 100 = 76.6\% \checkmark$			ALLOW 76.5 to 76.7%
28(c)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 67.6 % award 3 marks -----	3	3.1 × 3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	theoretical mass of aspirin = $2.00/138.0 \times 180.0 = 2.609 \text{ g} \checkmark$			$M(\text{C}_7\text{H}_6\text{O}_3) = 138.0$; $M(\text{C}_9\text{H}_8\text{O}_4) = 180.0$
	mass of pure aspirin made = $2.30 \times 0.7664 = 1.763 \text{ g} \checkmark$			ECF from (b)



Question 28 continued

Question	Answer	Marks	AO element	Guidance
	percentage yield = $1.763/2.609 \times 100 = 67.6\%$ ✓			ALLOW 67.5 to 67.6%. 81.0% (purity from (a)) scores 2; 88.2% (impurity ignored) scores 1
28(d)	The crude product is impure: its melting point is below 136 °C and it melts over a range ✓	2	1.1 × 2	Both lower and wider range
	Recrystallisation (from a hot solvent such as ethanol and water) ✓			
	Total	14		

Notes

What makes this hard: Aspirin reacts with two moles of NaOH (the ester and the carboxylic acid), and nothing tells you this. In (b), the impurity also reacts with NaOH, so you need two simultaneous equations, and the yield in (c) has to use the true purity.

(a) Aspirin has two groups that react with NaOH: the carboxylic acid and the ester. A 1 : 1 ratio gives a purity over 100%, which should prompt a rethink.

(b) An impurity that also consumes NaOH makes the back titration over-estimate the aspirin; the purity drops from 91.9% to 76.6%, and the yield in (c) is 67.6%, not 81.0%.

Question 29 Unified · Super hard · Thermodynamics and equilibrium: manufacturing methanol

Question	Answer	Marks	AO element	Guidance
29(a)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 413 K award 4 marks -----	4	3.1 × 4	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$\Delta H = -201.0 - (-110.5) = -90.5 \text{ kJ mol}^{-1}$ ✓			
	$\Delta S = 239.8 - (197.7 + 2 \times 130.7) = -219.3 \text{ J K}^{-1} \text{ mol}^{-1}$ ✓			Factor of 2 for H ₂ required
	Not feasible when $\Delta G > 0$: $T > \Delta H/\Delta S = -90.5/-0.2193$ ✓			Units converted to kJ
	$T = 413 \text{ K}$ ✓			ALLOW 412 to 413 K. 0.413 K scores 3 marks. ECF from ΔH and ΔS
29(b)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $4.22 \times 10^{-7} \text{ kPa}^{-2}$ award 4 marks -----	4	3.1 × 4	IF there is an alternative answer, check for any ECF credit possible using the working below.
	total amount = 1.500 mol; mole fractions: CO 0.167, H ₂ 0.333, CH ₃ OH 0.500 ✓			
	partial pressures: CO 1333 kPa, H ₂ 2667 kPa, CH ₃ OH 4000 kPa ✓			ALLOW MPa throughout
	$K_p = \frac{4000}{1333 \times 2667^2} = 4.22 \times 10^{-7}$ ✓			ALLOW 4.2×10^{-7} ; ALLOW 0.422 with units MPa ⁻²

Question 29 continued

Question	Answer	Marks	AO element	Guidance
	units: kPa^{-2} ✓			Units must match the pressure unit used
29(c)*	Level 3 (5 or 6 marks) A clear evaluation of temperature, pressure and catalyst, which uses the results of (a) and (b) and resolves the apparent conflict between feasibility and yield, with a justified conclusion. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 or 4 marks) An evaluation of at least two of temperature, pressure and catalyst, with some use of (a) or (b); or a clear evaluation of temperature and pressure without reference to the calculated results. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 or 2 marks) Some relevant comments on the conditions, with limited explanation. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	1.1 × 2 3.3 × 4	Indicative scientific points may include: Temperature - The forward reaction is exothermic: lower temperatures give a higher equilibrium yield and a larger K_p (a): ΔG is positive above about 413 K, so at 520 K the reaction is not feasible under standard conditions (100 kPa) - At lower temperatures the rate is too slow; 520 K is a compromise between rate and yield Pressure 3 mol of gas form 1 mol: high pressure shifts the equilibrium to the right (b): at 8 MPa the equilibrium mixture is 50% methanol by moles, so a good yield is obtained even though ΔG is positive at 100 kPa; the feasibility prediction applies to standard pressure - Higher pressures cost more (energy for compression, stronger plant) and increase safety risks Catalyst and recycling - The catalyst increases the rate by providing a route of lower activation energy, so a lower temperature can be used; it does not change K_p - Recycling unreacted CO and H_2 gives a high overall conversion even though each pass does not reach completion
	Total	14		

Notes

What makes this hard: Part (a) says the reaction is not feasible above 413 K, yet (b) shows a good yield at 520 K. The evaluation in (c) has to explain why: ΔG is for 100 kPa, and the high pressure moves the equilibrium to the right.

(a) and (b) appear to contradict each other. ΔG refers to all gases at 100 kPa; at 8 MPa the equilibrium lies well to the right, because the reaction reduces the number of gas molecules.

(b) Using 8.00 for the total pressure in kPa, or forgetting to square $p(\text{H}_2)$, are the two common slips.



Question 30 Unified · Super hard · Transition metal analysis: a green iron complex salt

Question	Answer	Marks	AO element	Guidance
30(a)(i)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 53.8 % award 3 marks -----	3	3.1 ×3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	$n(\text{MnO}_4^-) = 0.0200 \times 12.00/1000 = 2.40 \times 10^{-4} \text{ mol}$ ✓			
	$2\text{MnO}_4^- + 5\text{C}_2\text{O}_4^{2-} + 16\text{H}^+ \rightarrow 2\text{Mn}^{2+} + 10\text{CO}_2 + 8\text{H}_2\text{O}$: $n(\text{C}_2\text{O}_4^{2-}) = 2.5 \times 2.40 \times 10^{-4} \times 10 = 6.00 \times 10^{-3} \text{ mol in } 100.0 \text{ cm}^3$ ✓			Ratio 2 : 5 and scaling by 10 both needed
	mass = $6.00 \times 10^{-3} \times 88.0 = 0.528 \text{ g}$; percentage = $0.528/0.982 \times 100 = 53.8\%$ ✓			ALLOW 53.7 to 53.8%
30(a)(ii)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $\text{K}_3\text{Fe}(\text{C}_2\text{O}_4)_3 \cdot 3\text{H}_2\text{O}$ award 3 marks -----	3	3.1 ×3	IF there is an alternative answer, check for any ECF credit possible using the working below.
	water 11.0%; K by difference = $100 - 53.8 - 11.4 - 11.0 = 23.8\%$ ✓			ECF from (a)(i)
	moles per 100 g: K $23.8/39.1 = 0.609$; Fe $11.4/55.8 = 0.204$; C_2O_4 $53.8/88.0 = 0.611$; H_2O $11.0/18.0 = 0.611$ ✓			Ratio 2.98 : 1 : 2.99 : 2.99
	$\text{K}_3\text{Fe}(\text{C}_2\text{O}_4)_3 \cdot 3\text{H}_2\text{O}$ ✓			ALLOW $\text{K}_3[\text{Fe}(\text{C}_2\text{O}_4)_3] \cdot 3\text{H}_2\text{O}$
30(b)	+3 ✓	1	2.1	ECF from (a)(ii): charges must balance
30(c)	Two octahedral 3D diagrams, each with three bidentate ligands spanning adjacent (cis) positions ✓	2	2.5 ×2	
	The two drawn as non-superimposable mirror images (mirror line or clear reflection) ✓			
30(d)	The reaction is slow at first: two negative ions repel / high activation energy ✓	2	2.1 ×2	
	Mn^{2+} formed in the reaction catalyses it (autocatalysis), so the rate increases as Mn^{2+} builds up ✓			
30(e)	$2[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-} \rightarrow 2\text{Fe}^{2+} + 5\text{C}_2\text{O}_4^{2-} + 2\text{CO}_2$ ✓	2	2.1 ×2	Species correct
	Balanced for atoms and charge ✓			ALLOW complexed Fe(II) products, e.g. $2[\text{Fe}(\text{C}_2\text{O}_4)_2]^{2-}$, if balanced
	Total	13		



Question 30 notes continued

Notes

What makes this hard: No titration equation is given: you have to build the 2 : 5 ratio from half-equations. The potassium percentage comes by difference, and the slow start to the titration points to the Mn^{2+} ions acting as a catalyst.

(a)(i) The ratio $2 \text{MnO}_4^- : 5 \text{C}_2\text{O}_4^{2-}$ comes from the half-equations $\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}$ and $\text{C}_2\text{O}_4^{2-} \rightarrow 2\text{CO}_2 + 2\text{e}^-$.

(e) Each ethanedioate ion oxidised gives two electrons, enough to reduce two iron(III) ions; so one ethanedioate is lost as 2CO_2 for every two Fe^{3+} reduced.





Plumi

The iPad notebook for GCSE and A Level revision

Write your answers by hand. Each one is marked against that question's own mark scheme.

Stuck? The tutor nudges you with a hint before it gives anything away.

Practice adapts to you: the next question is chosen from what you have shown you can do.



Free on iPad · tryplumi.app

OCR-style practice written by Plumi. Not produced or endorsed by OCR.

