2025 ASSESSMENT REPORT

CHM415115 CHEMISTRY

General Comments

Students are reminded to:

- turn every page on the exam to not miss any questions
- not answer in the “Marker use” column
- use blue or black pen, not red pen
- use the spare diagrams provided at the back of each booklet; do not redraw your own version
- read the questions carefully before answering
- highlight only the important parts of the question; do not waste time highlighting almost all the question text.

Standard science abbreviations are acceptable (e.g. L.C.P = Le Chatelier’s Principle. S.T.P = Standard temperature and pressure), all other abbreviations need to be defined before they are used. (e.g. ON, O, R, C, A, Rxn, Em)

There is no need to rewrite what is already stated in the stimulus of the questions, this gains no marks and uses valuable time.

Answers need to reflect the command terms in the question (e.g. “state”, “explain”, “label”, “determine”, “outline”, “calculate”, “compare”) to gain marks.

If you need to cross out or scribble out an answer, the new answer must be clearly identified, clearly written and follow a logical sequence. A blank space on a neighbouring page (clearly referred to and labelled) or asking for a spare question booklet is acceptable.

Numerical answers in all parts of the exam, not just Criterion 8, require context (what is it?) and units to demonstrate understanding.

Consider the clarity of language used in answers. There is overlap in scientific language and general language in many areas of Chemistry. Accidental confusion in language use can make answers incorrect (e.g. ‘reduce’ can be used as a chemistry-specific term and as a general term for a decrease in something).

Giving incorrect answers/contradictory answers alongside the correct answer will not gain full marks. Marks are deducted for each incorrect statement.

Students should not simplify their responses according to phrases like “3 marks = 3 points in your answer”. Marks are allocated to specific points relevant to the question asked and stimulus given. Not all related points are mark-worthy. Some responses do not gain full marks without specific chemistry terminology. In the mark scheme below, you will see 0.5 marks awarded, not just whole marks.

TASMANIAN ASSESSMENT, STANDARDS & CERTIFICATION

Section A – Criterion 5

Students largely did well in this section of the exam, with the majority of students achieving 71% (32 out of 45) or higher. There was a wide range of accessible C standard questions, with over 85% of students demonstrating satisfactory understanding of electrochemistry.

A range of answers/language were accepted in explanatory responses. See the feedback below for each question on areas for improvement.

The Criterion 5 section is electrochemistry, and as such, including half-equations and discussion of relative oxidiser and reducer strengths are expected in explanatory questions. Refer to oxidising and reducing strengths rather than position on the E.C.S / S.R.P.

A number of students missed Question 6 (11 marks) as they did not turn past the “Blank Page”.

Question 1 feedback

a. Generally well answered.

b. Care should be taken when referring to and comparing species that are oxidisers or reducers. E.g. Zn is a reducer, Cu^{2+} is an oxidiser, ∴ their strengths cannot be directly compared. Zn reducing strength can be compared with Cu^{2+} conjugate pair, Cu. Cu itself is not present in the system.

   Observations were well answered. Most students referred to solution colour intensity. Note: Zn does not dissolve, nor does the Cu precipitate – these terms matter.

   This is a spontaneous reaction question, not an electrochemical cell, ∴ anode and cathode terms are inappropriate.

c. Care should be taken when referring to and comparing species that are oxidisers or reducers (Sn^{2+} vs Sn^{4+}, Fe^{2+} vs Fe^{3+})

   This is a spontaneous reaction question, not an electrochemical cell, ∴ anode and cathode terms are inappropriate.

Question 2 feedback

a. Generally well answered, with iv) being an exception to the Ox(H)=1 rule.

b. Students confidently compared oxidation states and linked to reduction and oxidising agents; however, many forgot to link to e^- transfer.

Question 3 feedback

Students coped well with this complex application of electrochemical cells.

a. Scaffolding of i) ii) iii) meant most students attempted all elements.

b. Students should label the anode and cathode with connecting lines to the electrode itself. Electrons should be shown moving through the wire, not through the air.

c. Many students were unsure whether to cancel out species or not. Correctly balanced variations were accepted.

d. Generally well answered with a range of valid purposes.

e. A number of students didn't identify the need for $Li \rightarrow Li^{+} + e^{-}$ half equation and E^0 value from the information sheet to solve this problem. 6.65 V was a common incorrect answer.

Question 4 feedback

a. Scaffolding of i) ii) iii) meant most students attempted all elements. Students should think about observations as what they can see in the experiment, not what they suspect the product is.

b. The majority of students forgot that Fe^{2+} appears on the ECS as an oxidiser AND a reducer. Both of these needed to be considered.

Question 5 feedback

a. Generally well answered. Clear setting out of calculation steps allowed for part marks to be awarded.

b. This was attempted by most but incorrectly multiplied by 83%, decreasing the yield further, rather than dividing by 83% to increase the yield to 100%. This demonstrated a large-scale misunderstanding amongst the cohort.

c. Most students correctly identified water to be the species being electrolysed; however, they did not always note the word 'cathode' in the question to select the correct half-equation (reduction of water to hydrogen gas). A common misconception was that the gas was produced from the sulphate ions.

Question 6 feedback

a. Generally, students made a good attempt at this question, gaining a range of marks. Students who drew a correct, fully labelled, diagram of the corrosion at the base of the pole, gained marks with fewer words in their explanation – saving time. The movement of electrons and the movement of ions were the most commonly missed aspects of the explanation. Students should not refer to the changing concentration of water, this is incorrect.

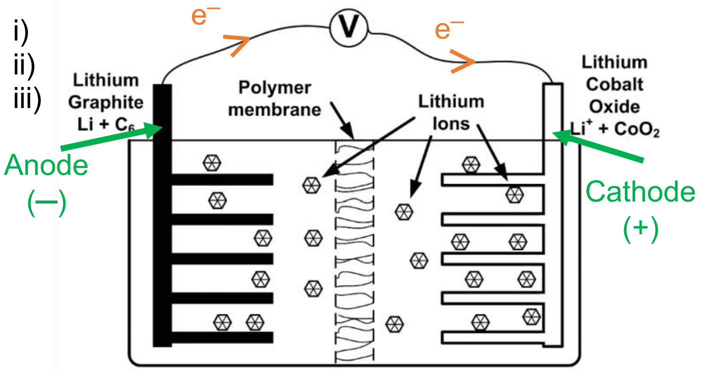
b. This question was not well answered. Not many students identified the change of bonding type between the iron metal and the rust as the source of the concrete cracking.

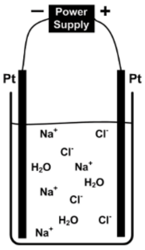
c. This question was well answered with a range of wording/explanations demonstrating the core information required.

d. This was very well answered with a range of methods mentioned by students with a bias towards more effective measures for this situation such as an applied EMF, sacrificial anodes or galvanising.

Solutions

Question	Sample answer	Marks	Comments / considerations for 2025 exam
1 a)	i. $MnO_4^{-}{}_{(aq)} + 8H^{+}{}_{(aq)} + 5e^{-} \rightarrow Mn^{2+}{}_{(aq)} + 4H_2O_{(l)}$	1	0 if incorrect. -0.5 for minor error.
	ii. $SO_3^{2-}{}_{(aq)} + H_2O_{(l)} \rightarrow SO_4^{2-}{}_{(aq)} + 2H^{+}{}_{(aq)} + 2e^{-}$	1	
	iii. $2MnO_4^{-}{}_{(aq)} + 16H^{+}{}_{(aq)} + 10e^{-} \rightarrow 2Mn^{2+}{}_{(aq)} + 8H_2O_{(l)}$ $5SO_3^{2-}{}_{(aq)} + 5H_2O_{(l)} \rightarrow 5SO_4^{2-}{}_{(aq)} + 10H^{+}{}_{(aq)} + 10e^{-}$ -- $2MnO_4^{-}{}_{(aq)} + 5SO_3^{2-}{}_{(aq)} + 6H^{+}{}_{(aq)} \rightarrow 2Mn^{2+}{}_{(aq)} + 5SO_4^{2-}{}_{(aq)} + 3H_2O_{(l)}$	1 (multiplication) 1 (net equation)	E.C.F from i) ii).
1 b)	EXPLANATION: A spontaneous reaction will occur since Cu^{2+} is a sufficiently strong oxidiser to oxidise Zn, a strong reducer. OR $E^{o}_{cell} = 0.76+0.34 = +1.1$ V. Positive E^{o}_{cell} represents a spontaneous reaction. EQUATIONS: $Cu^{2+}{}_{(aq)} + 2e^{-} \rightarrow Cu_{(s)}$ $Zn_{(s)} \rightarrow Zn^{2+}{}_{(aq)} + 2e^{-}$ OBSERVATION: Blue Cu^{2+} solution will fade Granules of Zn will decrease in size Brown $Cu_{(s)}$ will deposit	1 0.5 0.5 1	0 marks if E^{o}_{cell} negative. $\leftrightharpoons$ should not be used here. 1 valid observation required. “colour change” alone = 0 marks.

1 c)	Yes A spontaneous reaction will occur since Fe^{3+} is a sufficiently strong oxidiser to oxidise Sn^{2+}, a moderate reducer. OR $E^o_{cell} = 0.77 + {}^-0.15 = +0.62$ V. Positive E^o_{cell} represents a spontaneous reaction. $Fe^{3+}_{(aq)} + e^- \rightarrow Fe^{2+}_{(aq)}$ $Sn^{2+}_{(aq)} \rightarrow Sn^{4+}_{(aq)} + 2e^-$	0.5 0.5 0.5 0.5	
2 a)	i. Ox(Ti)=0	1	
	ii. Ox(Ti)=+4	1	
	iii. Ox(Ti)=+4	1	
	iv. Ox(Ti)=+2	1	metal hydride rule/exception.
2 b)	Oxidation state of Ti in $TiCl_4$ reduces from +4 to +2 in TiH_2 ∴ reduction is occurring, e^- is being transferred, making $TiCl_4$ an oxidising agent.	1 (ox states) 1 (e^- transfer)	E.C.F. from a). Half-equation approach accepted too.
3 a)	i) ii) iii)  *Figure 1*	1 anode / cathode labels 1 + / – polarity labels 1 e^- flow	E.C.F where appropriate from i).

3 b)	$Li + C_6 + Li^+ + CoO_2 \rightarrow C_6 + Li^+ + LiCoO_2$ OR $Li + CoO_2 \rightarrow Li^+ + CoO_2^-$ OR $Li + CoO_2 \rightarrow LiCoO_2$	1	Other correctly cancelled out variations were accepted. States not required. -0.5 if unbalanced.
3 c)	To provide a barrier between the half cells to prevent mixing of electrolytes. To complete the circuit by allowing ion movement between the two half cells. To prevent polarisation of the half cells as the cell operates.	1	Only 1 valid point required. "Salt bridge" alone was not accepted.
3 d)	$EMF = E^o(Li \rightarrow Li^+ + e^-) + E^o(CoO_2 + e^- \rightarrow CoO_2^-)$ $3.6 = 3.05 + E^o(CoO_2 \rightarrow CoO_2^-)$ $E^o(CoO_2 \rightarrow CoO_2^-) = 3.6 – 3.05$ $E^o(CoO_2 \rightarrow CoO_2^-) = 0.55$ V	1	-0.5 no unit.
4 a)	i. Cathode — Anode ii. $2H_2O_{(l)} + 2e^- \rightarrow 2OH^-_{(aq)} + H_{2(g)}$ — $2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+_{(aq)} + 4e^-$ iii. Bubbles (H_2) — Bubbles (O_2)  *Figure 2*	0.5 each (anode/cathode) 1 each (half-equations) 1 each (observation)	E.C.F. from i. to ii. and from ii. to iii. H_2 gas or O_2 gas alone were not accepted as the observation. Pop test, glowing splint test and pH tests were not accepted as observation.

4 b)	At the cathode: Fe^{2+} is a stronger oxidiser than H_2O and will be reduced to Fe. $Fe_{(s)}$ will form on the electrode. $Fe^{2+}_{(aq)} + 2e^{-} \rightarrow Fe_{(s)}$ At the anode: Fe^{2+} is a stronger reducer than H_2O and Cl^{-} and will be oxidised to Fe^{3+}. A brown solution will form around the electrode. $Fe^{2+}_{(aq)} \rightarrow Fe^{3+}_{(aq)} + e^{-}$	0.5 0.5 0.5 0.5	E.C.F. from a). For this Q only and for 2025 only: Cl^{-} oxidation was also considered at the anode. Eventual Fe^{3+} reduction was also considered at the cathode.
5 a)	$n(e-) = \frac{It}{F}$ $= \frac{50.0 \times 3600}{96500}$ $= \frac{50.0 \times 3600}{96500}$ $= 1.884\ \text{mol}$ As $Zn^{2+} + 2e^{-} \rightarrow Zn$ 2:1 ratio of e^{-} : Zn $n(Zn) = \frac{n(e-)}{2}$ $= \frac{1.884}{2}$ $= 0.942\ \text{mol}$ $m(Zn) = n \times M$ $= 0.942 \times 65.38$ $= 61.6\ \text{g}$	1 1 1	-0.5 no units.
5 b)	Multiple methods. Simplest is: $0.83 = \frac{1.00\ \text{h}}{x}$ $x = \frac{1.00}{0.83}$ $x = 1.20\ \text{h}$ $= 4340\ \text{s}$ OR Upscale the mass electrolysed to 100% yield and solve for t using the reverse calculation to 5 a).	1	-0.5 no units.

5 c)	The gas is likely to be $H_{2(g)}$. The E^o for the water reduction is very similar to the E^o for the Zn^{2+} reduction (-0.83 vs -0.76). OR The oxidising strength of water and Zn^{2+} are similar. As the $[Zn^{2+}]$decreases, it is likely that some water will be reduced, particularly if the emf is set to a high level.	1 0.5 0.5	
6 a)	In the presence of Fe, O_2 and H_2O an electrochemical cell forms on the pole. Due to different oxygen concentrations (differential aeration), the cathode will form where the oxygen concentration is the greatest, which is just above the ground. The anode will form where the oxygen concentration is the lowest, which is just below the ground. Cathode reaction $O_{2(g)} + 2H_2O_{(l)} + 4e^- \rightarrow 4OH^-_{(aq)}$. Anode reaction $Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^-$ (or combined reaction $Fe_{(s)} \rightarrow Fe^{3+}_{(aq)} + 3e^-$). Electron movement is within the metal pole from anode sites to cathode sites (towards the ground surface). Ion movement occurs within the soil, with the OH^- ions (and other anions in the soil) moving towards the anode sites, and Fe^{2+} ions (and other cations in the soil) moving towards the cathode sites. Inclusion of a good diagram showing equations and electron/ion movement in the pole would account for 4 marks (marks 2, 3, 4, 5 above). The final mark was allocated for one other valid point. This included, but not limited to, a suitable diagram, rust formation region, identifying rust products.	1 1 1 1 1 1	

6 b)	Metallic iron corrodes to ionic iron(III) hydroxide / iron(III) oxide. The ionic rust takes up more space than the metallic iron, expanding in the concrete and causing the concrete to crack. OR Fe^{2+} / Fe^{3+} ionic species are less dense than Fe metal and so during corrosion it expands causing the concrete to crack.	1 1	
6 c)	Fe is a stronger reducing agent than Sn. This makes the Fe pole the anode, and corrodes preferentially to the Sn. OR Sn is a weaker reducing agent than Fe. This makes the Sn pole the cathode and is protected, and the Fe pole the anode to be corroded. Fe and Sn in contact forms an electrochemical cell with an EMF, accelerating the oxidation of the Fe.	1 1	
6 d)	Any single sensible, valid response. • Applied EMF • Sacrificial anode • Galvanising • Painting • Nobel coating	1	

Section B – Criterion 6

Students largely did well in this section, with only very few receiving less than half marks.

This section tested students' knowledge of Le Chatelier's Principle (LCP) as applied to general equilibrium, more so than kinetics, reaction rates, thermochemistry, or acid/base equilibria.

Question 7 feedback

a. Most students were able to identify how $[CO_2]$ favours forward reaction of Equation 1 and describe LCP and how it applies.

   Most students were able to link an increase in $[H^+]$ with a decrease in pH.

b. Many students seemed to struggle with the competing equilibrium (as it's beyond the scope of the course) and how the net effect is an increase in $[H^+]$, with many using the increase in $[HCO_3^-]$ from Equation 2 to justify an increase $CaCO_{3\,(s)}$, despite the fact that $[HCO_3^-]$ must decrease according to Equation 3.

Question 8 feedback

a. Generally answered very well with few exceptions. Most marks were lost from failure to include states in reactants and products.
b. Generally answered very well. Marks were lost mainly due to some students adding invalid conditions for this scenario given the liquid states of these species (e.g. “an increase in pressure”) or not mentioning that reaction rate will increase.
c. Most students correctly identified an appropriate equilibrium condition with LCP explanation. Marks were lost mainly due to not stating that the favouring of products is the desirable result.

Question 9 feedback

a. Generally answered well.

b. The vast majority of students failed to identify the system as being in equilibrium (or possibly understand that, at equilibrium, reaction rates are equal and not 0), incorrectly stating the forward reaction as being faster than the reverse.

c. Part i. was generally answered better than Part ii.

   i. Marks were lost mainly due to not linking the increased $[\mathrm{CoCl_4^{2-}}]$ with the blue colour of the solution.

   ii. Many students incorrectly thought that adding HCl will affect $\mathrm{K_c}$ in some way.

d. Many students answered this correctly. Common errors were to discuss a dilution of colour intensity rather than a change in equilibrium.

e. Most students answered this well, identifying the precipitation of $\mathrm{Cl^-_{(aq)}}$ as the removal of a product, and then how this affects the equilibrium.

Question 10 feedback

a. Generally answered well. Lost marks mainly due to only providing limited details, usually not including why wood will not burn at normal temperature.

b. Generally answered well, often with students correcting for their mistake of converting the $\Delta\mathrm{T}$ value into kelvin by adding 273 (e.g. $\Delta\mathrm{T} = 17.0\ ^\circ\mathrm{C}$ is the same as $\Delta\mathrm{T} = 17.0\ \mathrm{K}$).

c. Many students were able to find E. Only some students realised / remembered that $\Delta\mathrm{H}$ can be expressed in $\mathrm{kJ\ g^{-1}}$.

   Some students, not realising this, endeavoured to find a mole value for wood to then find $\Delta\mathrm{H}$ in $\mathrm{kJ\ mol^{-1}}$. A notable number of students incorrectly used $\mathrm{M(O_2)}$ to find said mole value for wood.

   The number of students incorrectly attempting to use $\mathrm{mc}\Delta\mathrm{T}$ (using c for water and $\mathrm{m} = 3.10\ \mathrm{g}$) to find E was also not insignificant.

d. Most students were able to find the average rate of production of $\mathrm{CO_2}$.

e. Generally answered well.

f. Most students were able to sketch the increased initial rate and final volume being half. Marks were lost mainly due to lack of care taken to show half volume. Some students deciding to draw their own graph from scratch made it impossible to determine if their initial rate was faster.

Question 11 feedback

a. Many students answered this well. Marks were lost mainly due to only stating that “liquids are not included” without stating why.

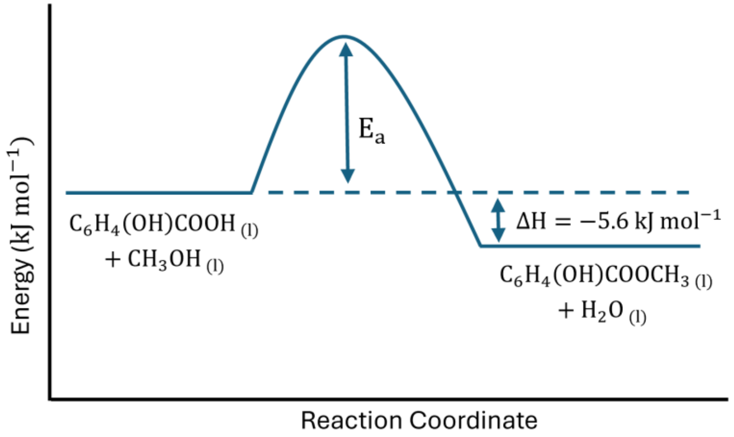
b. Generally answered well.

c. This was generally answered well, with students taking a variety of approaches.

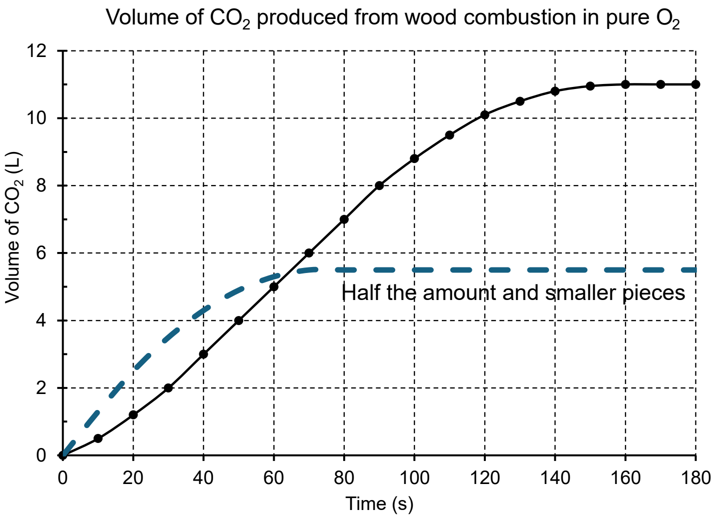
d. The wording of this question meant that many students interpreted “calculate the mass of water remaining” as asking for the mass of $H_2O_{(g)}$ with many successfully finding this. The intention of the questions was for students to determine the mass of *liquid* water $(H_2O_{(l)})$ remaining.

Solutions

Question	Sample Answer	Marks	Comments/ considerations for 2025 exam
7 a)	According to Le Chatelier’s Principle (LCP), an increase in $[CO_2]$ moves the equilibrium in Equation 1 to the right to lower $[CO_2]$, forming more H_2CO_3. According to LCP, an increase in $[H_2CO_3]$ will similarly increase the $[H^+]$ and $[HCO_3^-]$ in Equation 2. Again, according to LCP, an increase in $[HCO_3^-]$ will also increase the $[H^+]$ and $[CO_3^{2-}]$ in Equation 3. The increased $[H^+]$ from Equation 2 and 3 will decrease the ocean pH.	2 0.5 0.5 1	
7 b)	According to LCP, an increase in $[H^+]$ will cause the equilibrium in Equation 4 to shift to the right to decrease $[H^+]$. This decreases the amount of $CaCO_3$ in shellfish and plankton and forms more HCO_3^- and Ca^{2+}.	1 1	Answer must relate back to the effect on shellfish and plankton for full marks.

8 a)		1 for shape 1 for reactants and products labelled 1 for E_a 1 for ΔH	-0.5 if the reactants and products were labelled as “reactants” and “products”. -0.5 if states weren’t included for the reactants and products.
8 b)	High temperature. An increase in temperature increases the E_k of the particles. As particles move faster, this leads to more frequent collisions between particles **and** collisions are of higher energy (on average). ∴ more frequent successful collisions ∴ a faster reaction.	1 1 1	-0.5 if an invalid condition was chosen. Credit still given for correct understanding of kinetic theory.
8 c)	Possible answers: • Low temp. According to LCP, as temp is decreased the equilibrium will attempt to counteract the change by moving to the right, increasing the temp and ∴ increasing the yield of methyl salicylate. • Increase the amount of methanol. According to LCP the equilibrium will attempt to counteract the change and reduce the amount of methanol by shifting to the right and ∴ increase the yield of methyl salicylate. • Reduce the amount of $H_2O_{(l)}$ e.g. by adding a dehydrating agent. According to LCP, the equilibrium will attempt to counteract the change by shifting to the right, increasing the amount of $H_2O_{(l)}$ and ∴ increasing the yield of methyl salicylate.	1 for valid condition change 1 for LCP understanding 1 for linking to effect on methyl salicylate	
9 a)	$K_c = \frac{[Co(H_2O)_{6\,(aq)}^{2+}][Cl_{(aq)}^{-}]^4}{[CoCl_{4\,(aq)}^{2-}]}$	2	“$K_c =$” must be included.
9 b)	The rate of the forward reaction = the rate of the reverse reaction.	1	
9 c) i.	HCl is a source of Cl^- ions.	0.5	

	According to LCP an increase in $[\mathrm{Cl^-}]$ will cause the equilibrium to shift left to decrease $[\mathrm{Cl^-}]$. $\therefore$ $[\mathrm{CoCl_4^{2-}}]$ increases and $\therefore$ solution turns blue.	1 0.5	
9 c) ii.	No effect. *Explanation* (*not needed*): Temperature hasn't changed and $\mathrm{K_c}$ is only affected by a change in temperature.	1	
9 d)	Turns pink. *Explanation* (*not needed*): Adding water decreases concentration of all species. Since $[\mathrm{Cl^-}]$ is raised to the power of 4 in the expression, it has the greatest effect on the value of the reaction quotient, Q. $\therefore$ Q must decrease such that $\mathrm{Q} < \mathrm{K_c}$. The equilibrium will then move to favour the products, until equilibrium is reached and $\mathrm{Q} = \mathrm{K_c}$ by forming more products.	1	
9 e)	$\mathrm{Ag^+}$ forms a precipitate with $\mathrm{Cl^-}$, removing Cl^- from the solution. The equilibrium adjusts (LCP) by moving to the right, forming more $\mathrm{Cl^-}$. Therefore, solution turns pink.	1 0.5 0.5	
10 a)	At low temperature, particles have low $\mathrm{E_k}$, so no reaction. A spark increases the $\mathrm{E_k}$ of a few particles such that some collisions have $\mathrm{E_k} > \mathrm{E_a}$ and a reaction starts to occur. Since the reaction is exothermic, these few reactions produce energy making more collisions have $\mathrm{E_k} > \mathrm{E_a}$ which in turn react producing even more energy. This continues until the combustion is vigorous and becomes more difficult to stop (as in bush fires).	1 1 1 1 for positive feedback statement	A $\mathrm{E_k}$ distribution diagram could be used to assist answer. "Exothermic" must be stated in the response.
10 b)	$\mathrm{c_f} = \frac{\mathrm{Vit}}{\Delta\mathrm{T}}$ $= \frac{55 \times 11 \times 5 \times 60}{17.0}$ $= 10\,680\ \mathrm{J\ K^{-1}}\ (10.7\ \mathrm{kJ\ K^{-1}})$	1 1	

10 c)	$E = c_f \Delta T$ $= 10.68 \times 12.5$ $= 133.5 \text{ kJ}$ $\Delta H = \frac{E}{m}$ $= -\frac{133.5}{3.10}$ $= -43.1 \text{ kJ g}^{-1}$	1 1	
10 d)	Average rate $= \frac{5\text{L}}{1 \text{ min}} = 5 \text{ L min}^{-1}$ OR $= \frac{5}{60} = 0.083 \text{ L s}^{-1}$	1	Correct units must be included.
10 e)	Smaller pieces mean there is a greater surface area. A higher SA means there will be more frequent collisions between reactants, and ∴ more frequent effective collisions. ∴ faster reaction rate.	0.5 1 0.5	
10 f)		1 for steeper gradient 1 for plateau at 5.5L	
11 a)	$[H_2O_{(l)}]$ is effectively constant.	1	
11 b)	As temperature increases, according to LCP, the equilibrium shifts to decrease the temperature. This favours the endothermic direction. Since the forward reaction is endothermic, this increases the $[H_2O_{(g)}]$ and ∴ increasing K_c.	0.5 0.5 0.5 0.5	

11 c)	$PV = nRT,$ $\therefore n = \frac{PV}{RT}$ $= \frac{23.8 \times 24.5}{62.4 \times 298}$ $= 0.0314 \text{ mol}$ $[H_2O_{(g)}] = \frac{n}{V}$ $= \frac{0.0313}{24.5}$ $= 1.28 \times 10^{-3} \text{ mol L}^{-1}$ $= K_c$	1 1	A variety of approaches were accepted. Any volume could technically be used to arrive at the required answer. Students had to provide enough working to adequately show what the question was after.
11 d)	$n(H_2O_{(g)})$ in $2.0L = CV$ $= 1.28 \times 10^{-3} \times 2.0$ $= 2.56 \times 10^{-3} \text{ mol}$ $m(H_2O_{(g)})$ in $2.0L = nM$ $= 2.56 \times 10^{-3} \times 18.016$ $= 0.0461 \text{ g}$ $\therefore m(H_2O_{(l)})$ remaining $= 0.050 - 0.0461$ $= 0.0039 \text{ g}$ (or 0.004 g to correct significant figures)	2	A variety of approaches were accepted. Adequate logical working was required for full marks.

Section C – Criterion 7

This section of the examination was generally well answered with an average mark of about 30/45.

Students should be commended for consistency with hydrogens on organic chains and for attempting all questions.

Students should be aware of the language used in questions and understand what cognitive verbs are asking of them.

Question 12 feedback

a. Students who mentioned carbonyl groups and hydroxy groups only received half marks.

b.

   i. The diagram was generally well drawn, with only a few candidates drawing alternating single and double bonds between the carbon atoms.

   ii. A minority of students explained the structure satisfactorily. A common error was to say that the carbon-carbon bond length was 1.5 x the length of a single bond or to say that each carbon makes 1.5 bonds.

c.

   i. This question on solubility was generally poorly explained. Most candidates recognised the presence of polar functional groups and assumed the dipole-dipole bonding between the aspirin molecules prevented water from interacting. Many referred to the long carbon chains rather than the bulky non-polar aromatic ring.

      Many students incorrectly referred to hydrogen bonding as occurring within the molecules rather than between them.

   ii. Most candidates recognised that solubility would increase in the less polar solvent. Explanations were not required and not marked.

Question 13 feedback

a. Structural formulae were well drawn and butanamide correctly identified by a high percentage of candidates.

b. The table before the question confused some candidates who thought they needed to explain the difference in the melting points of alanine and lactic acid instead of explaining the high melting point of the amino acid. Good answers to the intended question were in a minority, with few candidates pointing out that the forces between the molecules determine the melting point. Most identified the presence of polar groups without explaining how the polar groups interact between molecules.

c. Most candidates identified one functional group instead of both the amine and carboxylic acid.

d. Condensation polymers for lactic acid were generally poorly drawn with little understanding of the ester linkages. A common mistake was putting an ‘O’ on either end of the polymer.

Question 14 feedback

a. Most candidates picked up at least 7 of the 9 possible marks by referring to their formula sheet. The copper catalyst often caused students issues, being the only reactant not on the formula sheet. They needed to show the negative charge on the alkoxide ion (product A) and the positive charge on the sodium ion to get the full mark. In some cases, candidates were given the benefit of errors carried forward.

b.

i. To get the full 2 marks, the wavenumbers for O-H stretching and the absence of the C=O stretching needed to be identified.

ii. To get the full 2 marks, students needed to identify the M^+ peak at $m/z = 60$ and show how this corresponded to molar mass of propanol and show how the base peak at $m/z = 31$ corresponds to CH_2OH^+. Alternatively, they could show that the molar mass of CH_3CH_2COOH was 74 g mol^{-1} and compare to provide M^+ peak.

Question 15 feedback

a. Most candidates scored 3 marks for the table. No marks were deducted for writing $3d^7$ before $4s^2$. Shorthand was accepted.

b. Candidates needed to show ionisation from the gaseous state.

c. This was generally poorly answered. To obtain full marks, an answer needed to include that the 4th electron was taken from a shell closer to the nucleus which has less shielding than electrons in the third shell resulting in a much stronger electrostatic force of attraction.

d. Most candidates recognised that the shielding was similar across period 3 and that the increase in the electrostatic force was due to the extra protons in the nucleus.

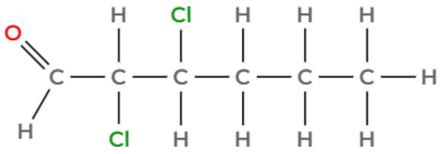
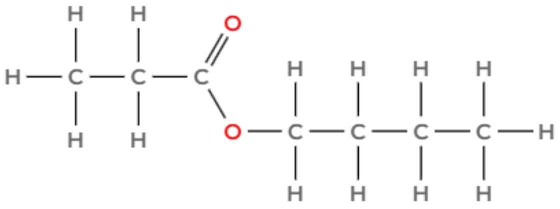
e. This was poorly answered by most candidates. To get full marks, the position of the 3p electron being further from the nucleus and experiencing greater shielding from the 2 inner shells and the 3s orbital needed to be recognised.

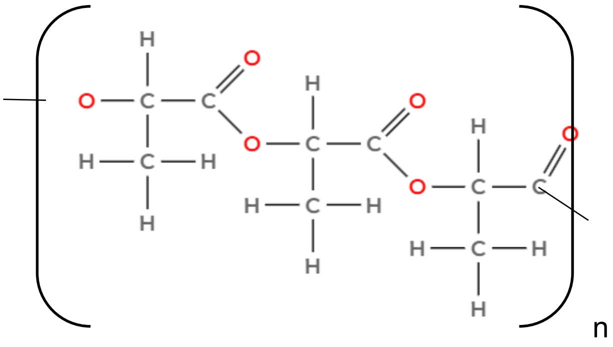
Question 16 feedback

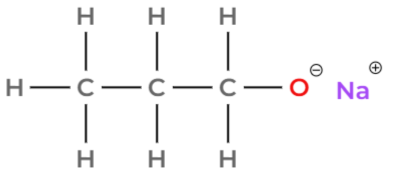
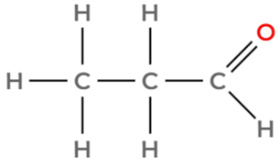
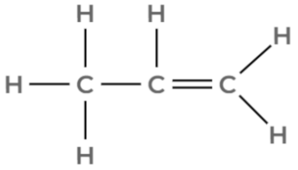
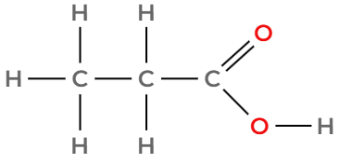
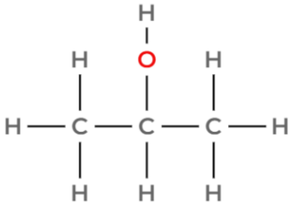
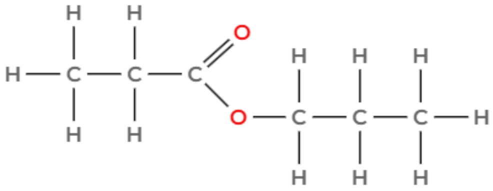
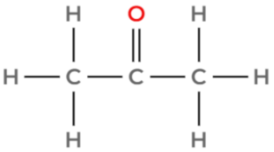
a. Most candidates scored at least 2/3 marks by recognising that kinetic energy and therefore the speeds of molecules increase with temperature. This results in an increase in collision frequency and the force of collisions with the balloon walls. To get the third mark students needed to explain how the gas molecules inside the balloon applied a larger force than those outside the balloon so that the balloon was forced to expand.

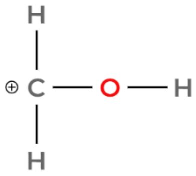
b. This question was poorly answered. Few students were able to identify the source of the larger intermolecular forces in SO_2 molecules as relating to dipole-dipole forces due to the electronegativity differences between S and O and the greater dispersion forces due to the larger number of electrons in an SO_2 molecule compared with He.

Solutions

Question	Sample Answer	Marks	Comments/ considerations for 2025 exam
12 a)	Carboxylic acid Ester	1 1	
12 b) i.	C_6H_6 	1	Other correct representations were given full marks.
12 b) ii.	6 C-C bonds are the same length, unlike that in the alternating double and single bond representation. Delocalisd electrons are shared around the six carbons in the benzene ring, this is represented by the circle in the middle of the C carbon ring.	1 1	
12 c) i.	Aspirin has reduced solubility **with water** due to water being polar and the presence of the large, non-polar aromatic ring. This disrupts the normally highly polar carboxylic acid group, reducing the solubility of asprin in water.	1 1	
12 c) ii.	Increase (*explanation not needed*) Ethanol is less polar than water, so the solubility of aspirin should increase.	1	
13 a) i.		1	- 0.5 for no hydrogens drawn.
13 a) ii.	butanamide	1	
13 a) iii		1	

13 b)	Alanine has strong intermolecular bonding, specifically H bonding, which requires more energy to break and hence melt the substance. The H bonding is due to the presence of **polar** amine and carboxylic acid groups.	1 1	A comparison to lactic acid was not required.
13 c)		1 (correct structure) 1 (3 repeat units)	Students must show the polymer continues.

14 a)	**A & H**  + H_2 **B**  **C**  **D**  **E**  **F & I**  + H_2O **G** 	1 each 1 1 1 1 1 1	Names not required. All Hs must be shown. Error carried forward through the question if applied correctly.
14 b) i.	Strong absorption at 3350 cm^{-1} is indicative of an alcohol OH being present. There is no strong absorption between 1650 – 1780 cm^{-1} for a C=O, so is not a carboxylic acid.	1 1	Wavenumbers must be included for full marks.

14 b) ii.	$M(C_3H_8O) = (3 \times 12.01) + (8 \times 1.008) + 16$ $= 60.094\ g\ mol^{-1}$ $M(C_3H_6O_2) = (3 \times 12.01) + (6 \times 1.008) + (2 \times 16)$ $= 74.078\ g\ mol^{-1}$ Molecular ion is present at 60, confirming propan-1-ol is present, not propanoic acid. **OR** $M(C_3H_8O) = (3 \times 12.01) + (8 \times 1.008) + 16$ $= 60.094\ g\ mol^{-1}$ Base peak at 31 represents propan-1-ol fragment seen below, which is not possible for propanoic acid.  	1 1	
15 a)	Al = $1s^22s^22p^63s^23p^1$ $S^{2-} = 1s^22s^22p^63s^23p^6$ Co = $1s^22s^22p^63s^23p^64s^23d^7$	1 1 1	Shorthand was accepted.
15 b)	$Al_{(g)} \rightarrow Al^{+}_{(g)} + e^{-}$	1	States are required.
15 c)	The first three ionisation energies are for removing the 3 electrons from the outer (3rd) shell. The fourth ionisation energy is removing an electron from the second shell. This shell has less inner electron shielding, is closer to the nucleus and is more strongly held, hence the large increase in ionisation energy.	1 1 0.5 0.5	
15 d)	Moving left to right within period 3: Constant shielding across the period. More protons in the nucleus. Attractive force from nucleus/electrostatic force attraction increases as you move across the table. Therefore more energy required to remove outer electron / increased ionisation energy.	1 1 1 1	

15 e)	The outer electron in Al is in the 3p orbital, which has greater electron shielding / further away from nucleus than the outer electron in Mg which is in the 3s orbital. Hence, lower ionisation energy.	1 1	Subshells must be discussed for full marks.
16 a)	When a gas is heated it gains E_k. An increase in E_k increases the speed of the gas particles. The faster moving particles means there will be more collisions with the balloon wall and each collision will exert a greater force. The greater force will cause the balloon to expand due to external force being lower.	0.5 0.5 0.5 0.5 1	
16 b)	Helium closely resembles an ideal gas as it has negligible intermolecular forces and its particle size is tiny. SO_2 has increased intermolecular forces due to molar mass and polarity. Hence, decreased volume due to greater attraction between molecules.	1 1 1	

Section D – Criterion 8

Overall, this section was well answered.

Many students lacked proficiency in both the identification and consistent application of significant figures.

A significant number of students also failed to communicate working sufficiently, e.g. numbers appearing without context.

Students must use the provided data as given and avoid subsequent rounding within the calculations until the final answers.

The frequent “show that” phrases led many students to make some incorrect assumptions as to which values were to be used for subsequent questions. Using the rounded or approximate amounts often led students to incorrect results for subsequent parts of the questions.

In Section D of the 2025 exam, markers applied a penalty of –0.5 marks only once for an incorrect application of significant figures and –0.5 marks for inappropriate rounding.

Question 17 feedback

Question 17 was very straightforward and hence most students answered it correctly.

A common error was neglecting the mass of the water when calculating the molar mass of borax.

Another common error was not applying the mole ratio to obtain the number of moles of sodium ions from both chemicals.

Question 18 feedback

a. Was answered well by most students, with a variety of approaches being awarded full marks. The markers would like to encourage teachers and students in future years to answer Hess' Law problems by showing their manipulation of the provided equations by writing out and summing to give the overall equation.

b. Was not well answered with students incorrectly applying the mole ratio to the heat of reaction.

Question 19 feedback

This question was generally answered well.

a. Most recognised this was a limiting reactant question and correctly identified the limiting reactant as O_2 but did not provide adequate evidence to justify this.

b. The most common mistake was not determining the moles of NH_3 consumed correctly. Another common error was incorrect use of reacting mole ratios.

c. Was very well answered. The most common mistake was not converting the temperature from °C to K.

Question 20 feedback

a. Was poorly answered. Many of the students confused properties of primary standards with properties of standard solutions. Some students incorrectly tried to find the properties of sodium oxalate.

b. Was generally answered well. A common error was failing to use the correct stoichiometric ratio.

c. Was answered well by nearly all who attempted it. The most common error was using the rounded value from part b instead of their calculated value.

d. Was also generally answered well by students. The most common error was not using the correct stoichiometric ratio of 5:1. Another common error was trying to find number of moles from the mass of the mineral sample.

e. Was not well answered. The most common error was determining the mass of iron using the moles of iron found in part d, instead of the concentration from part d. Students lost marks for not showing appropriate working. Students who had made a previous error also lost marks if they manipulated their working to obtain a "realistic value".

Question 21 feedback

a. Was reasonably well answered. The majority of students could construct the correct K_c equation. The most common error was not determining the moles/concentration of the reactants at equilibrium correctly. Another error was simply substituting the given values into the K_c expression. The inclusion of units for the K_c value was a source of confusion for some students.

Many students chose to use an ICE table which made their working clearer for markers.

b. Was generally well answered with most who attempted this question able to find Q. Students had to make a comparison to K_c for full marks.

There appeared to be some misconceptions about how the Q value can be used to determine the direction of the reaction with comparisons with 0 or 10^{-4} being incorrectly used. Another common error was answering that since Q was less than K_c, the reverse reaction would be favoured.

Question 22 feedback

As there was no scaffolding provided, this was a discriminating question.

The majority of students failed to correctly calculate the amount of OH^- ions in excess, including not applying a mole ratio from a balanced chemical equation or chemical formula for barium hydroxide.

Full marks were awarded to those who appropriately used the K_w expression or pOH equations. Many students failed to round their pH value to an appropriate number of significant figures.

Solutions

Question	Sample Answer **NOTE:** equations should be worked **down** the page. These are condensed to decrease the report size.	Marks	Comments/ considerations for 2025 exam
17 a)	$M(Na_2B_4O_7.10H_2O)$ = (22.99x2) + (10.81x4) + (16x7) + (10x(16+2(1.008)) = 381.38 g mol^{-1}	1	
	n(borax) = 47.5/381.38 = 0.1245 mol	1	
	c(borax) = 0.1245/0.200 = 0.623 mol L^{-1}	1	
17 b)	n(Na^+ in borax) = 0.050 x 0.623 x 2 = 0.0622 mol	1	
	n(Na^+ in Na_2CO_3) = 0.12 x 1.5 x 2 = 0.3600 mol	1	
	Total Na^+ moles = 0.0622 + 0.3600 = 0.422 mol	1	
	C(Na^+) = 0.422/(0.05 + 0.12) = 2.48 (or 2.5) mol L^{-1}	1	

18 a)	(Eqn 1 × -1) $SO_{2(g)} \rightarrow S_{(g)} + \cancel{O_{2(g)}}$ ΔH = +297 kJ (Eqn 2 × -2) $2H_2S_{(g)} \rightarrow \cancel{2H_2}_{(g)} + 2S_{(g)}$ ΔH = +40 kJ (Eqn 3 × 2) $\cancel{2H_2}_{(g)} + \cancel{O_{2(g)}} \rightarrow 2H_2O_{(g)}$ ΔH = -572 kJ $SO_{2(g)} + 2H_2S_{(g)} \rightarrow 3S_{(g)} + 2H_2O_{(g)}$ Using Hess' Law, ΔH = +297 + 40 –572 = -235 kJ (~ -230kJ)	1 1 1 1	
18 b)	n(S) = 40.0/32.06 = 1.248 mol 3:1 ratio, ∴ E = (1.248 x 235)/3 = 97.7 kJ	1 1	
19 a)	$n(NH_3)$ = 100.0/17.03 = 5.872 mol $n(O_2)$ = 100/32 = 3.125 mol $n(NH_3)_{required} = {}^{4}/_{3} \times n(O_2) = {}^{4}/_{3} \times 3.125 = 4.167$ mol As 4.167 < 5.872, NH_3 is in excess OR $n(O_2)_{required} = {}^{3}/_{4} \times n(NH_3) = {}^{3}/_{4} \times 5.872 = 4.404$ mol As 4.404 > 3.125, O_2 is the limiting reactant ∴ $n(N_2) = {}^{2}/_{3} \times n(O_2) = {}^{2}/_{3} \times 3.125 = 2.083$ mol ∴ $m(N_2)$ = 2.083 x 28.02 = 58.4 g Alternative approach: From NH_3: $n(N_2)$ = (100.0/17.03) x (2/4) = 2.936 mol N_2 From O_2: $n(N_2)$ = (100.0/32) x (2/3) = 2.0833 mol N_2 O_2 is the LR because it produced fewer moles of product $m(N_2)$ = 2.0833 x 28.02 = 58.4 g	0.5 0.5 1 1 1	

19 b)	$n(NH_3)_{reacted} = {}^{4}/_{3} \times n(O_2) = {}^{4}/_{3} \times 3.125 = 4.167$ mol $n(NH_3)_{remaining} = 5.872 - 4.167 = 1.705$ mol $m(NH_{3\ remaining}) = 1.705 \text{ x } 17.03 = 29.04$ g	1 1 1	
19 c)	$PV = nRT, \quad \therefore P = \frac{nRT}{V} = \frac{3.125 \text{ x } 0.0821 \text{ x } 298}{1}$ P = 76.4 atm (or 7740 kPa)	- 0.5 for each error	
20 a)	Any two of: • Must be chemically stable • Must be pure • High molecular mass • Not deliquescent or hygroscopic • Soluble.	0.5 for each property	Cheap and readily available were not accepted.
20 b)	$n(Na_2C_2O_4) = 0.025 \text{ x } 0.05227 = 1.306 \text{ x } 10^{-3}$ mol $n(MnO_4^-) = {}^{2}/_{5} \times n(Na_2C_2O_4)$ $\therefore n(MnO_4^-) = {}^{2}/_{5} \times 1.306 \text{ x } 10^{-3} = 5.22 \text{ x } 10^{-4}$ mol $\therefore c(MnO_4^-) = \frac{5.227 \text{ x } 10^{-4}}{0.0238} = 0.02196 \text{ mol L}^{-1}$	 1 1 1	
20 c)	$n(MnO_4^-) = 0.02196 \text{ x } 0.00710 = 1.56 \text{ x } 10^{-4}$ mol	1	
20 d)	$n(Fe^{2+}) = 5 \times n(MnO_4^-)$ $\therefore n(Fe^{2+}) = 5 \times 1.559 \times 10^{-4} = 7.796 \times 10^{-4}$ mol $c(Fe^{2+}) = \frac{7.796 \text{ x } 10^{-4}}{0.025} = 0.0312 \text{ mol L}^{-1}$	 1 1	
20 e)	$n(Fe^{2+})$ in 1000 mL = cV = 0.03119 x 1 = $3.119 \text{ x } 10^{-2}$ mol $\therefore m(Fe) = 55.85 \text{ x } 3.119 \text{ x } 10^{-2} = 1.74$ g $\therefore$ % Fe = 1.74/3.527 x 100 = 49.4 % by mass	1 1 1	

<table>
<tr>
<td>21 a)</td>
<td>
<table>
<tr><th></th><th>$n(O_2)$</th><th>$n(SO_2)$</th><th>$n(SO_3)$</th></tr>
<tr><td>I</td><td>1.3</td><td>2.1</td><td>0</td></tr>
<tr><td>C</td><td>-0.6</td><td>-1.2</td><td>+1.2</td></tr>
<tr><td>E</td><td>0.7</td><td>0.9</td><td>1.2</td></tr>
<tr><td>Conc</td><td>$\frac{0.7}{8} = 0.0875$</td><td>$\frac{0.9}{8} = 0.1125$</td><td>$\frac{1.2}{8} = 0.15$</td></tr>
</table>
$K_c = \frac{[SO_3]^2}{[O_2] \text{x} [SO_2]^2}$
$= \frac{0.15^2}{0.0875 \text{ x } 0.1125^2} = 20.3$
</td>
<td>2
1
1</td>
<td>Marks awarded for equivalent calculations without an ICE diagram.</td>
</tr>
<tr>
<td>21 b)</td>
<td>$Q = \frac{8.2^2}{0.29 \text{ x } 3.9^2} = 15.2$
$Q < K_c$ ∴ not at equilibrium
Forward reaction is favoured to increase Q.</td>
<td>1
0.5
0.5</td>
<td></td>
</tr>
</table>

22	$Ba(OH)_{2\,(aq)} + 2HCl_{(aq)} \rightarrow BaCl_{2(aq)} + H_2O_{(l)}$		pOH approach was given full marks if applied correctly.
	Net ionic equation: $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$		
	$n(H^+) = n(HCl) = 0.05 \times 0.00987 = 4.935 \times 10^{-4}$ mol	1	
	$n(OH^-) = 2 \times n(Ba(OH)_2) = 2 \times 0.0380 \times 0.0140$		
	∴ $n(OH^-) = 1.064 \times 10^{-3}$ mol	1	
	$n(OH^-)_{reacted} = 1 \times n(H^+) = 4.935 \times 10^{-4}$ mol		
	∴ $n(OH^-)_{remaining} = 1.064 \times 10^{-3} - 4.935 \times 10^{-4}$		
	$= 5.705 \times 10^{-4}$ mol	1	
	$[OH^-] = \frac{5.705\times10^{-4}}{(0.038+0.05)} = 6.483 \times 10^{-3}$ mol/L	1	
	Assume at 25℃, $K_w = [H^+][OH^-] = 1.0 \times 10^{-14}$		
	$\therefore [H^+] = \frac{1 \times 10^{-14}}{6.483 \times 10^{-3}} = 1.543 \times 10^{-12}$ mol/L	1	
	pH = $-\log_{10}[H^+] = -\log_{10}(1.543 \times 10^{-12}) = 11.8$	1	
	Alternative Method:		
	pOH = $-\log[OH^-] =$ -log$(6.483 \times 10^{-3}) = 2.188$		
	pH = 14 –2.188 = 11.8 (3 sig figs)		